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FINAL DEGREE PROJECT

Title: Packaging Sustainability Assessment

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1. Acknowledges

I would like to express my greatest gratitude to Vanesa Zorrilla Muñoz for her encouragement that guided me with her useful advice throughout the project. I would also like to thank my family and friends for their support and participation when I needed.

2. Abstract

Packaging is an essential part of the majority of products in the actual market. Therefore, packaging design must draw attention to improve its sustainable character in order to satisfy consumers, enhance its environmental performance and keep economic costs to a minimum.

Measuring packaging's sustainability would provide consumers information so as to raise awareness and, moreover, a tool that would help companies to find product weaknesses to be improved.

For that purpose, this project has defined a Sustainability Index that measures with a 100-point scale the sustainable character of seven food and beverage packaging. The index contains the three pillars of sustainability which are environment, economy and society. These sustainable indicators are represented by the following variables: carbon footprint, product price, value for money, product preservation and openability.

The seven containers will be compared in sustainable terms and finally one of them will be selected to be redesigned. The new design will try to improve the worst scoring variables and its overall sustainable character.

List of acronyms

Acronym	Definition
EPI	Environmental Performance Index
EU	European Union
GHG	Greenhouse gas
GMP	Global warming potential
ISO	International Organization for Standardization
MAGRAMA	Ministerio de Agricultura, Alimentación y Medio Ambiente
PDCA	Plan-Do-Check-Act
PET	Polyethylene terephthalate
RIC	Resin Identification Code
SIP	The Plastics Industry Trade Association

3. Introduction

Packaging is not exclusive from the contemporary age; in fact, its origin stretches back into prehistory. Animal and fruit skins were used to keep and carry water, as first attempts of packaging, and meat could have been wrapped with leaves in order to be preserved. Need for food preservation became stronger when nomadic tribes turned into sedentary, since the gathered provisions had to be stored. There is archaeological evidence dating to 8000 BC of clay pots and jars that could have kept products such as oils and salt. Afterwards, the discovery of sand fusion at high temperatures would lead to the first glass packaging, easing the store of liquids [1].

The Industrial Revolution, which began in the late 18th century, marked a great growth in the development of packaging. The large-scale production had to distribute its products to the retail trade, and retailers had to preserve them until their sale. In the beginning, there was no information for the client about the origin or quality of the product because the possibility of an alternative purchase was likely low. It was not until the 19th century that packaging started to state on their labels the name of the producer or brand, an indicator of the origin and quality of goods [2].

Apart from the technological development enhanced by the Industrial Revolution, it increased massively the greenhouse gases emissions. These gases seem to be the cause of climate change, a theory supported by most part of the scientific community, which affirms the existence of enough samples in the past about the relation between changes in the GHG concentration and global climate changes [3].

The greenhouse effect is a natural phenomenon necessary for life, so the problem is not its existence but its increment. Part of the solar radiation reflected by the Earth's surface, greenhouse gases reradiate it back so they act as temperature regulators. These gases, which are found naturally in the atmosphere, are water vapour (H_2O), carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), ozone (O_3) and nitrous oxide (N_2O). Unfortunately, an increase of their concentration triggers a warmer atmosphere [4, 5].

In the second half of the 20th century the awareness of this issue began to rise; hence the first ecologist organizations appeared. The United Nations Conference on the Human Environment (Stockholm, 1972), was the first time that environmental issues were taken into account and it marked the development of the international policy in environment [6].

This conference was followed by the Brundtland Report (1987) which introduced the concept of sustainable development defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [7].

The Kyoto Protocol, adopted in 1997, establishes for the first time targets to reduce GHG emissions (by 5%) in the main developed countries and with economies in transition. A decade later, the European Union set climate and energy targets to be met by 2020, in which one of the objectives is a 20% reduction in EU GHG emissions from 1990 levels. Beyond the 2020 targets, the European Commission proposed in 2010 a roadmap for the EU to become a competitive low carbon economy by 2050, for what GHG emissions would be reduced by 80% compared to 1990. This roadmap suggests that domestic emission reductions of the order of 40% and 60% below 1990 levels would be the cost-effective pathway by 2030 and 2040, respectively [3, 8-11].

Clearly, packaging life cycle plays an important role in the generation of greenhouse gases and other environmental impacts. In order to prevent and reduce the impact contributed by packaging and its wastes, in 1994 it was adopted the European Parliament and Council Directive 94/62/CE. This directive established national measures concerning the management of packaging and packaging waste, such as minimum recycling percentages by weight of the totality of packaging materials contained in packaging waste; these targets were 25% for 2001 and 55% for 2008 [12, 13].

These measures encouraged the recovery and recycling of packaging among the European countries, as it is displayed in figure 1, a plot built from statistical data collected between 2005 and 2011.

Sometimes the concepts of recovery and recycling are thought to be the same when they are not. On the one hand, recycling is the collection of a product by the public and the return of this material to the industrial sector, where they are remanufactured. On the other hand, recovery is the collection of waste as mixed refuse where the materials are removed and finally returned to the industrial sector for remanufacturing. Then, the difference between both processes is that in recycling the material collection is done by the consumers [14].

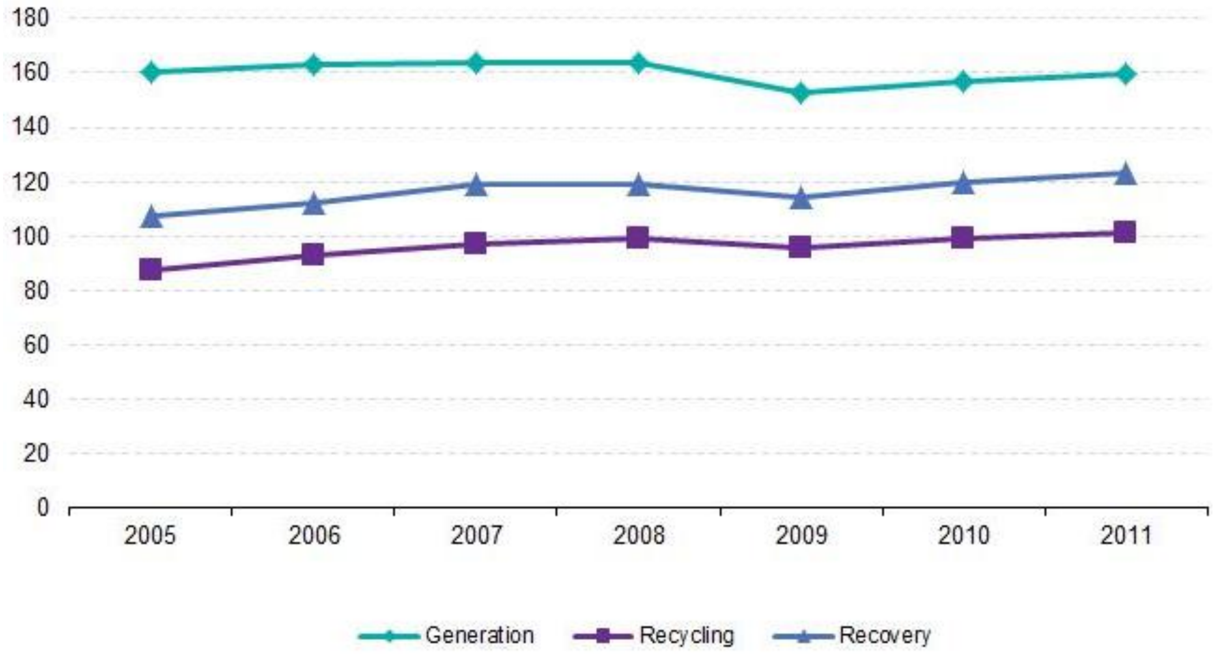

Figure 1: Development of overall packaging waste generated, recovered and recycled, EU-27, 2005-2011 (Kg per capita) [13]

In figure 1, the positive slope is noticed for both indicators, what means European countries are improving their sustainable behaviour. These variables seem to depend on each other sharing a correlation coefficient of 0.989.

Looking in detail for each one of the Member States:

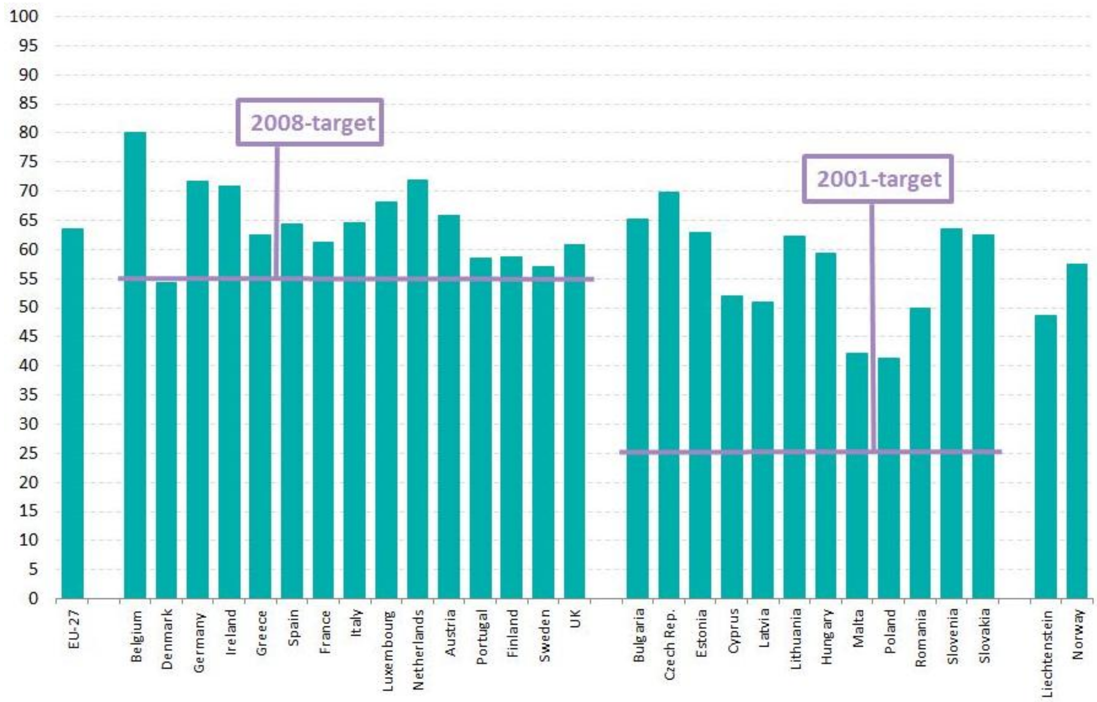

Figure 2: Recycling rate of packaging waste, 2011 (in % by weight) [13]

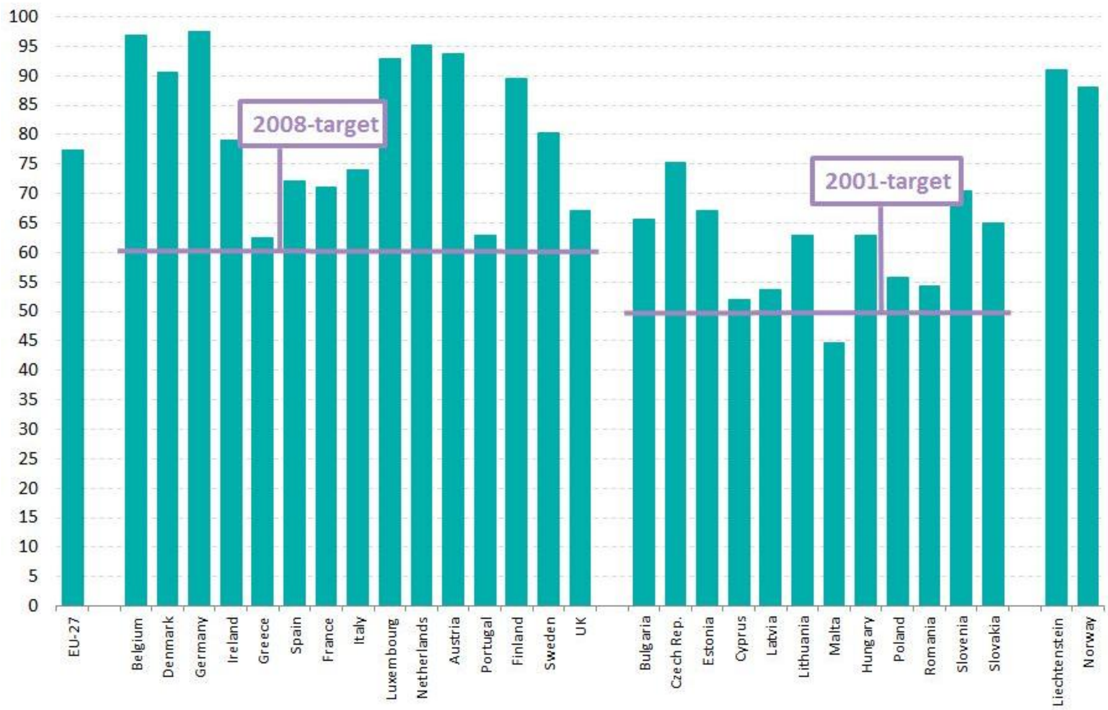

Figure 3: Recovery rate of packaging waste, 2011 (in % by weight) [13]

Figures 2 and 3 tell that nearly every European country met the established targets. Only Malta, with the 2001-target in the recovery rate, and Denmark, with the 2008-target in the recycling rate, could not achieve the directive requirements.

Due to the measures of prevention and reduction of packaging and packaging waste, many companies have changed their productive processes in order to comply with policies; besides, they promote an image of implication with environment. So, e.g. Unilever is a company that provides information about its own goals in recycling, reusing and reduction of its packaging products. Therefore, a company assessment is no longer defined exclusively by the financial part but with social and environmental contributions too; these three axes are also known as the pillars of sustainability in the Triple Bottom Line concept [15-17].

In relation to the concern of organizations about their environmental performance and its achievement, the International Organization for Standardization [18], has carried out International Standards that address the concept of continual improvement referred to a product life cycle. This concept is based on a methodology called Plan-Do-Check-Act which consists in establishing the goals, implement the changes required to meet the objectives, monitor the results of these changes and finally take actions to improve the process. ISO 14006:2011 puts together previous International Standards covering the three knowledge areas (design, environment and management systems) required to incorporate ecodesign within an environmental management system that conducts the PDCA methodology [19-21].

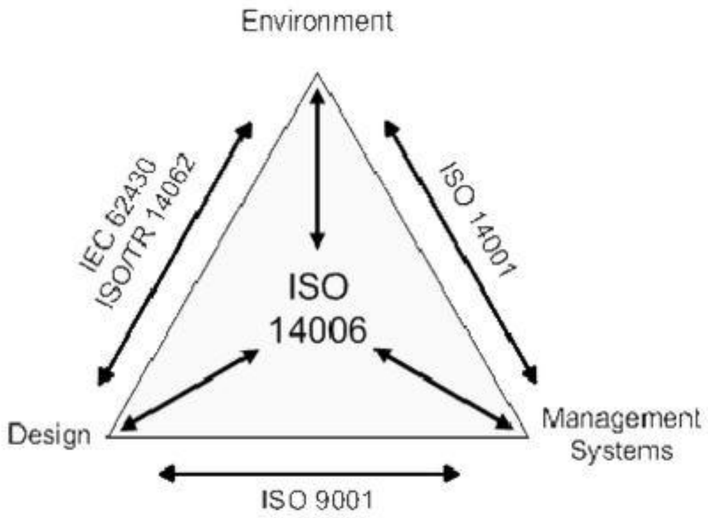

Figure 4: Relationship between ISO 14001, ISO 9001, ISO/TR 14062, IEC 62430 and ISO 14006 and the functional areas of knowledge [19]

Figure 4 illustrates the knowledge areas that are incorporated in each one of the standards; ISO 9001 addresses the relation between the product design and the management system of the organization, but the environmental factor is omitted. Meanwhile, ISO 14001 deals with environmental management systems and ISO/TR 14062 focus on product design regarding its environmental impact. However, only ISO 14006 assembles design, environment and management systems.

These International Standards give guidance for those organizations willing to create sustainable products by an iterative process.

Monitoring the process is crucial since it is in this phase where strengths and weaknesses of the resulting product are revealed, being able to revise the changes executed before. So returning to the idea of sustainability, how do companies measure if their products have been manufactured in a sustainable way? The answer is collecting relevant data about their production process related to sustainability; choosing suitable indicators will help to provide the required information [22, 23].

4. Objectives

The objectives of this project are assessing the grade of sustainability of seven different food and beverage packaging, available in the actual Spanish market, and redesigning one of them to improve its sustainable character.

The grade of sustainability will be measured by the calculation of an index which contains environmental, economic and social variables related to the packaging. Then, one of the packages will be selected to be redesigned in order to increase its value in terms of sustainability.

5. Personal motivation

The reason that has led me to choose this topic is the vast quantity of waste generated worldwide: The total waste generated in the European member states by all economic activities and households amounted to 2.515 million tonnes in 2012 [24].

Great part of this waste ends in landfills that may pollute air, water and soil or they even reach the bottom of the ocean harming all kind of species. Incineration is another alternative, but this could result in emissions of dangerous air pollutants. On the other hand, waste represents an inefficient use of resources that should serve for new products instead of being disposed [24, 25].

Among the kinds of waste generated, packaging waste represents a significant share in the total amount since the majority of products need a package. Therefore, in this project I focused on how to measure the packaging sustainable performance in order to improve it and raise awareness [13].

6. Methodology

This section is dedicated to explain the methodology used to achieve the objectives presented above.

First of all, the seven food and beverage packages are described. The selection took into consideration those containers which were available in the actual Spanish market and widely used in the daily life of average households.

Secondly, the assessment of sustainability is defined. This evaluation is based in the Triple Bottom Line principles in which the measurement of sustainability includes environment, economy and society. Then, environmental, economic and social variables are presented and it is explained how to collect and transform them into values than can be easily compared. The assessment is concluded by the Sustainability Index that determines which packaging is the best performing [17, 26].

Finally, the steps to redesign a package are explained following the Cradle to Cradle model [27].

6.1. Selected containers and packages

The selected containers and packages for the study of sustainability are the following:

- Metallic can of cola.

It is a packaging made of steel that contains 33 centilitres of cola, which is a common carbonated beverage.

Illustration 1: Metallic bottle of cola [28]

- Plastic bottle of cola.

It is a packaging made of polyethylene terephthalate, a plastic with 1 as its resin identification number.

Illustration 2: Plastic bottle of cola [29]

- Plastic yogurt cup.

Its packaging material is polystyrene since its resin identification number is 6. It contains 125 grams of yogurt.

Illustration 3: Plastic yogurt cup [30]

- Glass yogurt cup.

The packaging is made of glass and it contains 135 grams of yogurt.

Illustration 4: Glass yogurt cup [31]

- Plastic egg carton.

This packaging is made of PET and it contains 12 eggs.

Illustration 5: Plastic egg carton [32]

- Cardboard egg carton.

Its packaging material is cardboard and it contains 10 eggs.

Illustration 6: Cardboard egg carton [33]

- Paper rice packaging.

It is made of paper and it contains 1 kilogram of rice.

Illustration 7: Paper rice packaging [34]

The products and packaging described above were selected for the present study because all of them are usually consumed by the majority of households in their daily life, therefore, social indicators would be easily obtained. Another reason was the availability of information about the materials used for the packaging, especially in the case of plastic containers which have the Resin Identification Code in their bases.

The Resin Identification Code is a coding system developed in 1988 by SIP, The Plastics Industry Trade Association [35], "used solely to identify the plastic resin used in a manufactured article [36]". Thanks to the RIC code we can know the type of plastic used in the packaging, since there are a wide variety of resins according to their properties.

This project uses two methodologies: one of them for the analysis of sustainability and the other for redesigning the selected packaging.

6.2. Assessment of sustainability

The assessment of sustainability is conducted by the calculation of an index that takes account of the three factors that involve the concept of sustainability; these factors were measured with the indicators presented in the following table.

Indicators	Environmental	Carbon footprint
	Economic	Product price
	Social: Customer satisfaction	Value for money
		Product preservation
		Openability

Table 1: Indicators and variables

Each group of indicators is obtained in different ways; therefore, this project defines a methodology for the three of them.

6.2.1. Environmental indicator

Carbon footprint is related to the packaging material expressed in kilograms of carbon dioxide equivalents per kilogram of product ($KgCO_2e$/Kg of product). It is a measure that quantifies the GHG emissions released by a defined population, system or activity calculated as carbon dioxide equivalents, CO_2e, using the 100-year time horizon global warming potential [37-39].

GWP measures the amount of heat that a greenhouse gas traps in the atmosphere compared with carbon dioxide. That is to say, how many times does the gas in question trap the amount of heat absorbed by carbon dioxide? Although this is calculated over a time span of 20, 100 or 500 years, the most commonly used is the 100-year time horizon [40, 41].

The methodology used for the carbon footprint calculation is the one suggested by Ministerio de Agricultura, Alimentación y Medio Ambiente [42], that consists in the application of the following formula:

$$\text{carbon footprint} = \text{activity data} * \text{emission factor}\ [\mathrm{KgCO_2e}] \quad (1)$$

Where activity data is a parameter that quantifies the activity for which the carbon footprint will be calculated and emission factor is the quantity of GHG emissions related for each unit of the activity parameter; MAGRAMA provides a table of emission factors for each packaging material [43].

Packaging material	Emission factor (Kg CO_2e/Kg)
Glass	1,35E-06
Metals	3,32E-05
Paper and cardboard	3,32E-05
Plastics	3,32E-05

Table 2: Emission factors related to packaging materials [42]

These emission factors are related to the treatment received by materials. Metals, paper and cardboard and plastics have the same emissions factors because they are recycled by Ecoembes [44]. Although glass is recycled too, its treatment is not performed in the same organization as the other materials so that is why its emission factor is different.

It must be remarked that the carbon footprint values obtained will only represent the environmental impact of the packaging materials' recycling treatment. Then, only a small part of the life cycle is being consider when assessing environmental performance.

In the case of a packaging carbon footprint, the activity data will be its weight. To obtain the weight we will use a digital balance with a precision of 0,1 grams.

Illustration 8: Digital balance [45]

The packaging weight will be the average mean of eight measures in the digital balance, so that errors are minimised.

Once we have the carbon footprint related to a packaging, we must transform the indicator to a scale that can be easily compared with the other packaging because each one contains different quantities of their product. Then, in order to normalise the indicator, it can be divided by the quantity of product that contains expressed in kilograms, so finally the chosen unit of measurement for carbon footprint is kilograms of carbon dioxide equivalents per kilogram of product ($KgCO_2e$/Kg of product). Therefore, formula (2) is used for the indicator calculation.

$$\text{carbon footprint} = \frac{\text{packaging weight} * \text{emission factor}}{\text{product quantity}} \left[\frac{\text{KgCO}_2\text{e}}{\text{Kg of product}}\right] \tag{2}$$

6.2.2. Economic indicator

Although total cost of packaging would be the suitable variable to measure resources consumed during packaging's manufacturing, the selected economic variable is product price. This variable, which refers to the product and its packaging and includes taxes and the margin profit, has been chosen because it is the final price perceived by consumers; hence, it takes into account the social impact that has great significance in the index. These prices have been consulted in a current supermarket and they are expressed in Euros (€) [46].

However, here there is the same problem as in the carbon footprint indicator: it is necessary a value that can be compared among the selected packages that contain different quantities of product. Therefore, to normalise the indicator the procedure will be the same explained above: product price indicator will be divided by the quantity of product that each packaging contains expressed in kilograms, so in the end the unit of measurement will be Euros per kilogram of product (€/Kg of product).

$$\text{product price} = \frac{\text{Actual product price}}{\text{product quantity}} \left[\frac{€}{\text{Kg of product}}\right] \tag{3}$$

6.2.3. Social indicators

The social indicators chosen are the following:

- Value for money: "used in reference to something that is well worth the money spent on it [47]". In other words, it is the quality-price ratio of the product.
- Product preservation: it represents the preservation and protection level that offers the packaging to the product.

- Openability: “the quality or characteristic of being able to be opened [48]”. That is to say, is the packaging easy to open?

The parameters tested in this section are subjective; indicators like value for money or openability depend highly on the consumer’s point of view. Thus, in order to obtain them, a survey has been conducted to 201 consumers of the products to study; these are the questions asked for each packaging:

- Does the product price correspond with the product and packaging quality given?
- Is the product well preserved and protected by its packaging?
- Is the packaging product easy to open?

Besides, there is an additional question not related with any packaging but with consumer’s behaviour towards sustainability:

- Would you be willing to pay a higher price for products with sustainable packaging?

The survey finishes asking participants their sex and age. This information is treated as sociodemographic independent variables that enable to analyse opinions taking into account the “type” of consumer depending on their sex and age.

The sex and age of the participants are shown in figures 5 and 6, respectively.

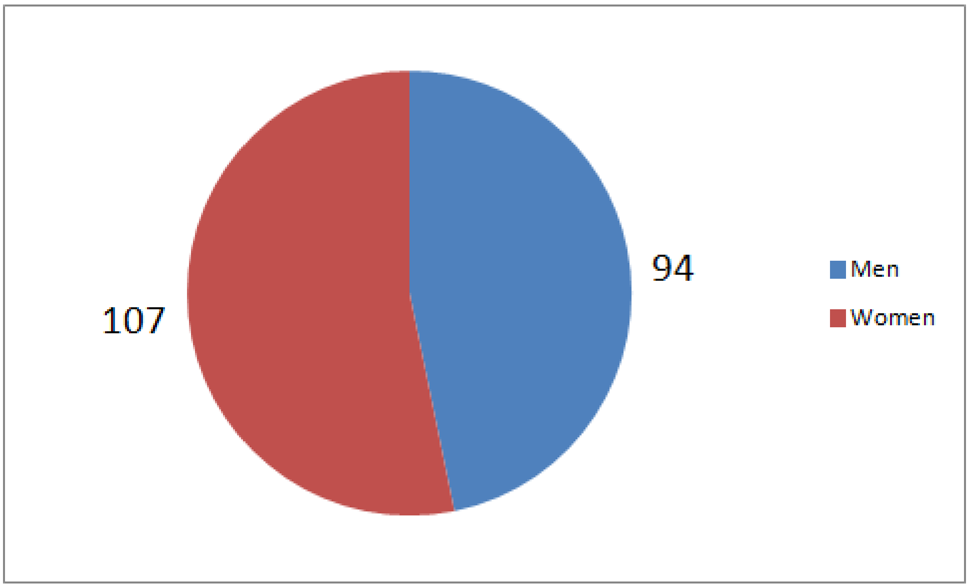

Figure 5: Sociodemographic independent variable: Sex

Figure 5 reveals 53,23% of participants are women and the rest are men, therefore, the conducted survey has almost an equally participation according to consumers' sex.

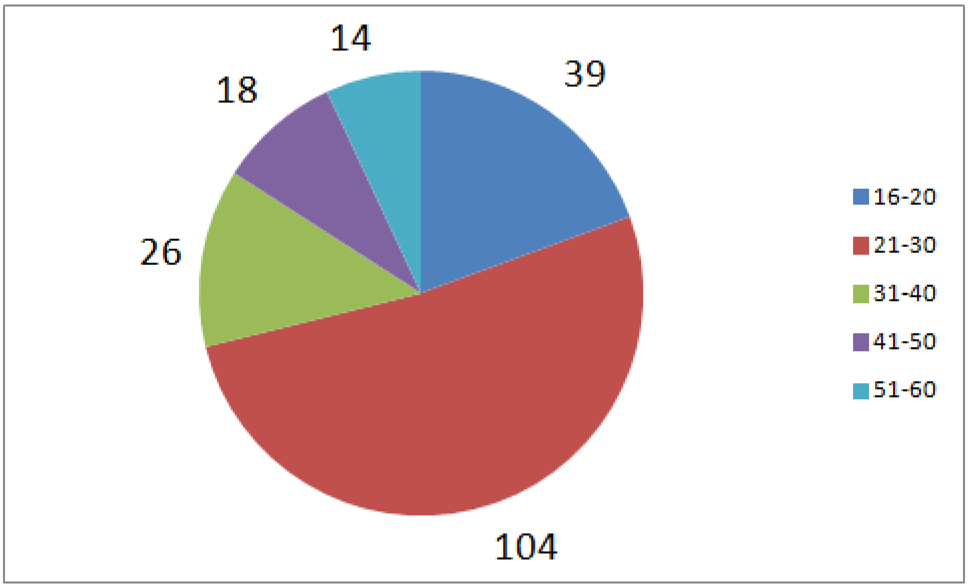

Figure 6: Sociodemographic independent variable: Age

Figure 6 tells participants present an age range of 16 to 60 years. However, in this case the participation is not equal since only the range of consumers who are 16 to 30 constitute 71,14% of the total.

All the information and opinions collected from consumers will remain anonymous.

The responses of the survey were registered using a Likert-type scale (1 = strongly disagree; 3 = strongly agree). A Likert scale is a psychometric scale used in surveys that contain correlated items (questions) in order to measure constructs like skills and knowledge or attitudes. In the case, there are two constructs or indicators: The social satisfaction of consumers towards a product's packaging and the environmental behaviour of consumers. The Likert scale assigns a value for each item of the questionnaire, so that qualitative variables turn to quantitative and can be easily analysed with statistical tools [49, 50].

However, before analysing survey's results it is advisable to determine if its questions or variables provide a reliable response of the indicator to measure. For that purpose we will calculate the Cronbach's alpha of the survey, a coefficient used in Statistics to estimate a test's reliability [51, 52].

The Cronbach's alpha is calculated for an indicator with multiple variables. That is why we will not calculate the coefficient for the indicator of the sustainable behaviour of consumers, since it is only represented by one question in the survey. But the other indicator has three variables, so its Cronbach's alpha should be obtained with formula (4).

$$\alpha = \frac{K}{K-1} * \left[1 - \frac{\Sigma {S_i}^2}{{S_T}^2}\right] \qquad (4)$$

Where:

K: number of variables

S_i^2: variance of each variable

S_T^2: variance of the sum of the variables

If (4) is applied to the case in question, taking the answers of 6 random consumers:

Consumer	Variable 1	Variable 2	Variable 3	Sum of variables
1	3	2	3	8
2	3	3	3	9
3	1	3	3	7
4	1	1	1	3
5	3	3	3	9
6	2	2	3	7
Variance	0,80555556	0,55555556	0,55555556	4,138888889
Sum of variances	1,91666667			
Cronbach's alpha	0,80536913			

Table 3: Calculation of Cronbach's alpha

K=3

S_1^2=0,80555556

S_2^2=0,55555556

S_3^2= 0,55555556

ΣS_i^2=1,91666667

S_T^2=4,138888889

$$\alpha = \frac{3}{3-1} * \left(1 - \frac{1{,}91666667}{4{,}138888889}\right) = 0{,}80536913$$

The Cronbach's alpha obtained is 0,8. Therefore, the indicator is well measured by the three variables in the survey because the nearer the coefficient's value is to 1, the more reliable it is [53].

6.2.4. Index calculation

Having collected the necessary information for the selected variables, it is time to calculate the index of sustainability. In order to obtain a reliable global measure, the scientific methodology developed by the Yale Center for Environmental Law and Policy [54] has been consulted to calculate the Environmental Performance Index [55]. EPI measures the environmental performance of 178 countries, taking into account the ecosystem vitality and the environmental health of each region.

The chosen packages to study could be considered countries: Each one has unique characteristics and their data need to be treated according to their situation. That is to say sustainable targets cannot be the same, e.g. product price, for metallic and plastic packaging because their production process is different. Then, the steps to follow for the index calculation are described.

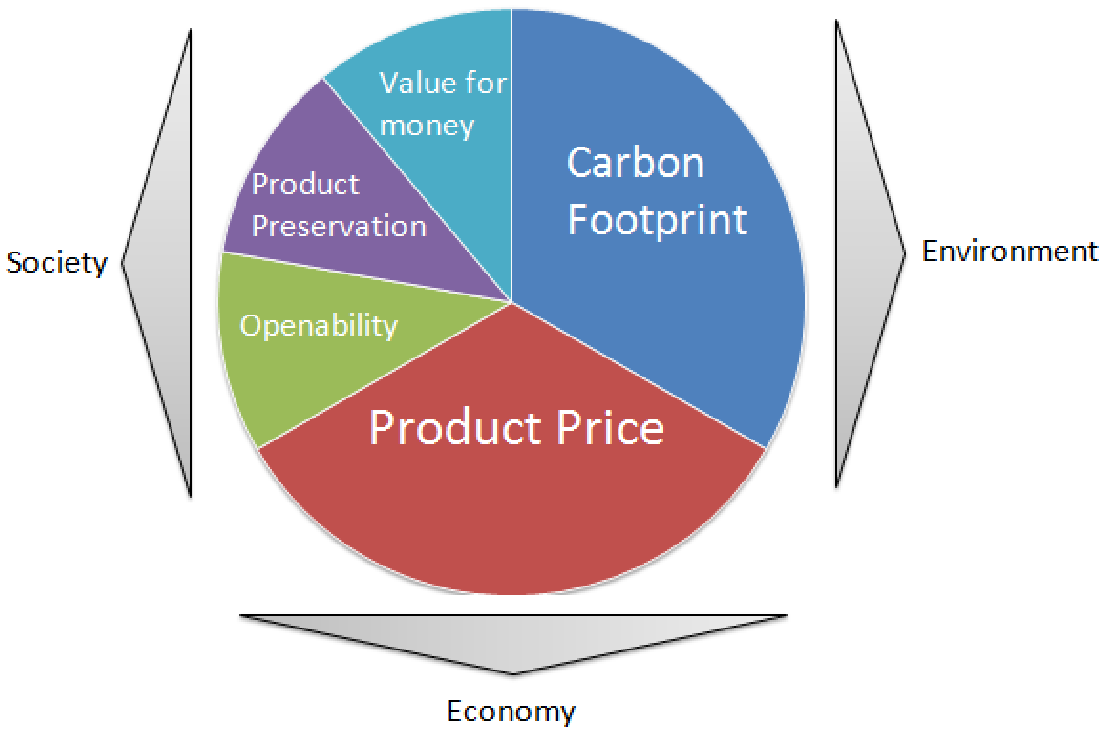

Figure 7: Components of Sustainability Index

As it is noticed from Figure 7, there are five indicators for the fields of environment, economy and society. The environmental and economic data have only one single value, but social data were taken from a survey done to 201 consumers. To obtain a representative value, the arithmetic mean is calculated for “value for money”, “product preservation” and “openability”.

Now it is necessary to convert data to indicators so that they can be compared in the same scale. To achieve this, data must be normalised with formula (5).

$$\text{indicator} = \frac{\text{packaging range} - \text{distance to target}}{\text{packaging range}} * 100 \tag{5}$$

This formula is based on the proximity-to-target method that measures each packaging's performance on any given indicator based on its position within a range established by the lowest performing packaging and the target. The index is measured with a scale of 100 points, so the lowest performing value will be equivalent to 0 and the target value will be 100.

An indicator's target will be determined by the best value observed among the studied packaging and the lowest performing value will be the worst value. For example, to compare three consumer's opinions about product preservation which have scored 1,5, 2 and 2,5 (in a Likert scale from 1 to 3, where 3 means the best performance), the target value for product preservation would be 2,5 and its lowest performing value would be 1,5.

As a consequence of setting target and lowest performing values in this way, the sustainability index will have a relative character. That is to say, if the sustainable performance of 10 packaging is assessed and one of them obtains the best possible score in the index, this does not mean its sustainability cannot be improved; this score means that packaging is the best performing one among all the studied. Then, what the sustainability index tells is how sustainable is a packaging compared to another or others.

Taking this into account formulas (6) and (7) are obtained.

$$\text{packaging range} = |\text{target value} - \text{lowest performing value}| \tag{6}$$

$$\text{distance to target} = |\text{target value} - \text{actual value}| \tag{7}$$

Absolute values are used to determine Distance to Target in order to transform “negative data”, like product price or carbon footprint, in which high values mean a poor sustainable performance. This transformation grants that the higher the index, the better the sustainable performance is. For the example of product preservation, its packaging range would be 1.

Formula (8) is used to calculate the indicator value.

$$\text{indicator} = \frac{\text{packaging range} - |\text{target value} - \text{actual value}|}{\text{packaging range}} * 100 \tag{8}$$

Next step is assigning weights to indicators so they can contribute to a single measure. The overall score will be obtained thanks to a linear aggregation shown in (9) [56].

$$\text{SI} = \alpha * (\text{environment}) + \beta * (\text{economy}) + \gamma * (\text{society}) \tag{9}$$

Where:

$\text{SI} = \text{Sustainability Index}$

$\alpha * (environment) = \alpha_1 * (\text{carbon footprint})$

$\beta * (\text{economy}) = \beta_1 * (\text{product price})$

$\gamma * (\text{society}) = \gamma_1 * (\text{value for money}) + \gamma_2 * (\text{product preservation}) + \gamma_3 * (\text{openability})$

As it can be seen, the term environment is only measured by carbon footprint, and the term economy is represented by product price. Therefore, α and β will be equivalent to α_1 and β_1, respectively, as it is represented in (10) and (11).

$$\text{environment} = \text{carbon footprint} \rightarrow \alpha = \alpha_1 \tag{10}$$

$$\text{economy} = \text{product price} \rightarrow \beta = \beta_1 \tag{11}$$

However, society is the contribution of three indicators that we will assume they contribute equally in the social performance. Then, γ must be the sum of γ_1, γ_2 and γ_3.

$$\text{society} = \text{value for money} + \text{product preservation} + \text{openability} \rightarrow$$
$$\gamma = \gamma_1 + \gamma_2 + \gamma_3 = 3 * \gamma_1 \tag{12}$$

α, β and γ must be determined and, again, they will impact equally on the final index. Then their values are obtained resolving the linear system (13).

$$\begin{Bmatrix} \alpha + \beta + \gamma = 1 \\ \alpha = \beta \\ \alpha = \gamma \end{Bmatrix} \tag{13}$$

$$\alpha = \beta = \gamma = \frac{1}{3} \tag{14}$$

Now α_1, β_1 and γ_1 are obtained automatically by the relations explained above:

$$\alpha_1 = \alpha = \frac{1}{3} \tag{15}$$

$$\beta_1 = \beta = \frac{1}{3} \tag{16}$$

$$\gamma_1 = \frac{\gamma}{3} = \frac{1}{9} \tag{17}$$

The final formula for the index calculation is shown in (18) [57].

$$\mathrm{SI} = \frac{1}{3} * carbon\ \mathrm{footprint} + \frac{1}{3} * \mathrm{product\ price} + \frac{1}{9} * \mathrm{value\ for\ money} + \frac{1}{9} * \mathrm{product\ preservation} + \frac{1}{9} * o\mathrm{penability} \tag{18}$$

6.3. Redesign of packaging

Once sustainability indexes for all packaging have been calculated and compared, one of the packages will be redesigned trying to improve the worst scoring variables.

Besides, the redesign will be based in the Cradle to Cradle model which suggests the imitation of nature’s processes. Resources are classified in biological nutrients, which are biodegradable materials that can be discomposed or technical nutrients which are materials that can be recycled without losing quality. Therefore, a product life cycle is a closed loop process free of waste [27, 58].

7. Results

Results for the seven food and beverage packages are shown in table 4. These are the calculated and collected values of carbon footprint as environmental variable, product price as economic variable and value for money, product preservation and openability as social variables.

Packaging	Carbon footprint	Product price	Value for money	Product preservation	Openability
Metallic can of cola	2,69E-03	1,72	2,15	2,6	2,64
Plastic bottle of cola	1,72E-03	1,53	2,10	2,28	2,68
Plastic egg carton	1,79E-03	1,75	2,08	2,11	2,39
Cardboard egg carton	2,38E-03	1,4	2,48	2,44	2,74
Plastic yogurt cup	1,23E-03	2	2,50	2,47	2,74
Glass yogurt cup	8,70E-04	7,41	1,84	2,72	2,34
Rice paper packaging	3,80E-04	1,52	1,99	2,5	2,35

Table 4: Carbon footprint (KgCO2e/Kg of product), product price (€/Kg of product), value for money, product preservation and openability

Now target and lowest performing values of indicators can be set by comparing results in table 4. Besides, packaging range is calculated according to the formula introduced in the methodology:

$$\text{Packaging Range} = |\text{target value} - \text{lowest performing value}| \qquad (6)$$

Indicators	Target value	Lowest performing value	Packaging range
Carbon footprint	3,80E-04	2,69E-03	2,31E-03
Product price	1,40	7,41	6,01
Value for money	2,50	1,84	0,66
Product preservation	2,72	2,11	0,61
Openability	2,74	2,34	0,4

Table 5: Target value, lowest performing value and packaging range of indicators

Having determined target and lowest performing values for the proximity-to-target methodology, each packaging situation is analysed.

7.1. Metallic can of cola

The first indicator to calculate is carbon footprint, for what the weight of a metallic can of cola with a 33cl capacity is needed. These are the results of the weight measures:

Weight measures (g)								Average weight (g)
26,3	26,3	26,4	26,3	26,4	26,4	26,3	26,3	26,3375

Table 6: Weight measures and average weight for a metallic can of cola of 33cl (g)

Remembering how to calculate the carbon footprint indicator, the value presented in table 7 expressed in kilograms of carbon dioxide equivalents is obtained.

$$\text{carbon footprint} = \text{activity data} * \text{emission factor}\ [\text{KgCO}_2\text{e}] \qquad (1)$$

However, for the index calculation carbon footprint is expressed in $KgCO_2e$/Kg of product.

$$\text{carbon footprint} = \frac{\text{packaging weight}*\text{emission factor}}{\text{product quantity}} \left[\frac{\text{KgCO}_2e}{\text{Kg of product}}\right] \qquad (2)$$

Average weight (Kg)	Emission factor ($KgCO_2e$/Kg)	Carbon footprint ($KgCO_2e$)	Product quantity (Kg)	Carbon footprint ($KgCO_2e$/Kg of product)
26,3375E-03	3,32E-05	8,74E-04	325,525E-03	2,69E-03

Table 7: Calculation of carbon footprint indicator (KgCO2e/Kg of product)

Next step is the calculation of the economic indicator represented by product price.

$$\text{product price} = \frac{\text{actual product price}}{\text{product quantity}} \left[\frac{€}{\text{Kg of product}}\right] \qquad (3)$$

According to the indicator formula, the value for product price shown in table 8 is calculated.

Actual product price (€)	Product quantity (Kg)	Product price (€/Kg of product)
0,56	325,525E-03	1,72

Table 8: Calculation of product price indicator (€/Kg of product)

Finally, in order to find out the social performance, a survey was conducted to 201 consumers so data could be collected for three indicators: value for money, product preservation and packaging openability. These indicators were measured in a scale from 1 to 3, meaning 3 the best social performance.

Value for money	Product preservation	Openability
2,15	2,6	2,64

Table 9: Social indicators

After collecting and calculating indicators, they must be normalized into a scale of 100 points because that will be the scale of the sustainability index.

$$\text{indicator} = \frac{\text{packaging range} - |\text{target value} - \text{actual value}|}{\text{packaging range}} * 100 \qquad (8)$$

Indicator	Actual value	Target value	Packaging range	Indicator value
Carbon footprint	2,69E-03	3,80E-04	2,31E-03	0
Product price	1,72	1,4	6,01	94,68
Value for money	2,15	2,50	0,66	46,97
Product preservation	2,6	2,72	0,61	80,33
Openability	2,64	2,74	0,4	75

Table 10: Values for indicators (100 point scale)

Once indicators have been transformed into a scale of 100 points, the sustainability index can be calculated.

$$\text{SI} = \frac{1}{3} * \text{carbon footprint} + \frac{1}{3} * \text{product price} + \frac{1}{9} * \text{value for money} + \frac{1}{9} * \text{product preservation} + \frac{1}{9} * \text{openability} \qquad (18)$$

Taking indicators' results, the sustainability index is obtained for a metallic can of cola with 33cl of capacity:

$$\text{SI} = \frac{1}{3} * 0 + \frac{1}{3} * 94{,}68 + \frac{1}{9} * 46{,}97 + \frac{1}{9} * 80{,}33 + \frac{1}{9} * 75 = 54{,}04$$

7.2. Plastic bottle of cola

Results for weight measures:

Weight measures (g)								Average weight (g)
26,9	27,0	26,8	26,8	26,7	26,7	26,7	26,8	26,8

Table 11: Weight measures and average weight for a plastic bottle of cola of 50cl (g)

Carbon footprint expressed in kilograms of carbon dioxide per kilogram of product:

Average weight (Kg)	Emission factor ($KgCO_2e/Kg$)	Carbon footprint ($KgCO_2e$)	Product quantity (Kg)	Carbon footprint ($KgCO_2e$/Kg of product)
26,8	3,32E-05	8,90E-04	517,3375E-03	1,72E-03

Table 12: Calculation of carbon footprint indicator (KgCO2e/Kg of product)

Product price expressed in Euros per kilogram of product:

Actual product price (€)	Product quantity (Kg)	Product price (€/Kg of product)
0,79	517,3375E-03	1,53

Table 13: Calculation of product price indicator (€/Kg of product)

Value for money, product preservation and openability:

Value for money	Product preservation	Openability
2,1	2,28	2,68

Table 14: Social indicators

Values of indicators measured in a scale of 100 points:

Indicator	Actual value	Target value	Packaging range	Indicator value
Carbon footprint	1,72E-03	3,80E-04	2,31E-03	41,99
Product price	1,53	1,40	6,01	97,84
Value for money	2,1	2,50	0,66	39,39
Product preservation	2,28	2,72	0,61	27,87
Openability	2,68	2,74	0,4	85

Table 15: Values for indicators (100 point scale)

Sustainability index for a plastic bottle of cola with 50cl of capacity:

$$SI = \frac{1}{3} * 41{,}99 + \frac{1}{3} * 97{,}84 + \frac{1}{9} * 39{,}39 + \frac{1}{9} * 27{,}87 + \frac{1}{9} * 85 = 63{,}53$$

7.3. Plastic egg carton

Results for weight measures:

Weight measures (g)								Average weight (g)
40,8	40,8	40,7	40,8	40,9	40,8	40,8	40,7	40,7875

Table 16: Weight measures and average weight for a plastic egg carton of 12 eggs (g)

Carbon footprint expressed in kilograms of carbon dioxide per kilogram of product:

Average weight (Kg)	Emission factor ($KgCO_2e/Kg$)	Carbon footprint ($KgCO_2e$)	Product quantity (Kg)	Carbon footprint ($KgCO_2e$/Kg of product)
40,7875E-03	3,32E-05	1,35E-03	754,65E-03	1,79E-03

Table 17: Calculation of carbon footprint indicator (KgCO2e/Kg of product)

Product price expressed in Euros per kilogram of product:

Actual product price (€)	Product quantity (Kg)	Product price (€/Kg of product)
1,32	754,65E-03	1,75

Table 18: Calculation of product price indicator (€/Kg of product)

Value for money, product preservation and openability:

Value for money	Product preservation	Openability
2,08	2,11	2,39

Table 19: Social indicators

Values of indicators measured in a scale of 100 points:

Indicator	Actual value	Target value	Packaging range	Indicator value
Carbon footprint	1,79E-03	3,80E-04	2,31E-03	38,96
Product price	1,75	1,40	6,01	94,18
Value for money	2,08	2,50	0,66	36,36
Product preservation	2,11	2,72	0,61	0
Openability	2,39	2,74	0,4	12,5

Table 20: Values for indicators (100 point scale)

Sustainability index for a plastic egg carton containing 12 eggs:

$$\mathrm{SI} = \frac{1}{3} * 38{,}96 + \frac{1}{3} * 94{,}18 + \frac{1}{9} * 36{,}36 + \frac{1}{9} * 0 + \frac{1}{9} * 12{,}5 = 49{,}81$$

7.4. Cardboard egg carton

Results for weight measures:

Weight measures (g)								Average weight (g)
45,1	45,0	45,0	45,0	45,0	45,0	45,1	44,9	45,0125

Table 21: Weight measures and average weight for a cardboard egg carton of 10 eggs (g)

Carbon footprint expressed in kilograms of carbon dioxide per kilogram of product:

Average weight (Kg)	Emission factor ($KgCO_2e/Kg$)	Carbon footprint ($KgCO_2e$)	Product quantity (Kg)	Carbon footprint ($KgCO_2e$/Kg of product)
45,0125E-03	3,32E-05	1,49-03	628,875E-03	2,38E-03

Table 22: Calculation of carbon footprint indicator (KgCO2e/Kg of product)

Product price expressed in Euros per kilogram of product:

Actual product price (€)	Product quantity (Kg)	Product price (€/Kg of product)
0,88	628,875E-03	1,40

Table 23: Calculation of product price indicator (€/Kg of product)

Value for money, product preservation and openability:

Value for money	Product preservation	Openability
2,48	2,44	2,74

Table 24: Social indicators

Values of indicators measured in a scale of 100 points:

Indicator	Actual value	Target value	Packaging range	Indicator value
Carbon footprint	2,38E-03	3,80E-04	2,31E-03	13,42
Product price	1,40	1,40	6,01	100
Value for money	2,48	2,50	0,66	96,97
Product preservation	2,44	2,72	0,61	54,10
Openability	2,74	2,74	0,4	100

Table 25: Values for indicators (100 point scale)

Sustainability index for a cardboard egg carton containing 10 eggs:

$$\mathrm{SI} = \frac{1}{3} * 13{,}42 + \frac{1}{3} * 100 + \frac{1}{9} * 96{,}97 + \frac{1}{9} * 54{,}10 + \frac{1}{9} * 100 = 65{,}70$$

7.5. Plastic yogurt cup

Results for weight measures:

Weight measures (g)								Average weight (g)
4,6	4,6	4,6	4,7	4,6	4,7	4,6	4,6	4,625

Table 26: Weight measures and average weight for a plastic yogurt cup of 125g (g)

Carbon footprint expressed in kilograms of carbon dioxide per kilogram of product:

Average weight (Kg)	Emission factor ($KgCO_2e/Kg$)	Carbon footprint ($KgCO_2e$)	Product quantity (Kg)	Carbon footprint ($KgCO_2e$/Kg of product)
4,625E-03	3,32E-05	1,54E-04	125E-03	1,23E-03

Table 27: Calculation of carbon footprint indicator (KgCO2e/Kg of product)

Product price expressed in Euros per kilogram of product:

Actual product price (€)	Product quantity (Kg)	Product price (€/Kg of product)
0,25	125E-03	2

Table 28: Calculation of product price indicator (€/Kg of product)

Value for money, product preservation and openability:

Value for money	Product preservation	Openability
2,5	2,47	2,74

Table 29: Social indicators

Values of indicators measured in a scale of 100 points:

Indicator	Actual value	Target value	Packaging range	Indicator value
Carbon footprint	1,23E-03	3,80E-04	2,31E-03	63,20
Product price	2	1,40	6,01	90,02
Value for money	2,50	2,50	0,66	100
Product preservation	2,47	2,72	0,61	59,02
Openability	2,74	2,74	0,4	100

Table 30: Values for indicators (100 point scale)

Sustainability index for a plastic yogurt cup with 125g of product:

$$\mathrm{SI} = \frac{1}{3} * 63{,}20 + \frac{1}{3} * 90{,}02 + \frac{1}{9} * 100 + \frac{1}{9} * 59{,}02 + \frac{1}{9} * 100 = 79{,}85$$

7.6. Glass yogurt cup

Results for weight measures:

Weight measures (g)								Average weight (g)
87,0	86,9	87,0	87,0	86,9	86,9	87,0	87,0	86,9625

Table 31: Weight measures and average weight for a glass yogurt cup of 135g (g)

Carbon footprint expressed in kilograms of carbon dioxide per kilogram of product:

Average weight (Kg)	Emission factor ($KgCO_2e/Kg$)	Carbon footprint ($KgCO_2e$)	Product quantity (Kg)	Carbon footprint ($KgCO_2e/Kg$ of product)
86,9625E-03	1,35E-06	1,17E-04	135E-03	8,70E-04

Table 32: Calculation of carbon footprint indicator (KgCO2e/Kg of product)

Product price expressed in Euros per kilogram of product:

Actual product price (€)	Product quantity (Kg)	Product price (€/Kg of product)
1	135E-03	7,41

Table 33: Calculation of product price indicator (€/Kg of product)

Value for money, product preservation and openability:

Value for money	Product preservation	Openability
1,84	2,72	2,34

Table 34: Social indicators

Values of indicators measured in a scale of 100 points:

Indicator	Actual value	Target value	Packaging range	Indicator value
Carbon footprint	8,70E-04	3,80E-04	2,31E-03	78,79
Product price	7,41	1,40	6,01	0
Value for money	1,84	2,50	0,66	0
Product preservation	2,72	2,72	0,61	100
Openability	2,34	2,74	0,4	0

Table 35: Values for indicators (100 point scale)

Sustainability index for a glass yogurt cup with 135g of product:

$$\mathrm{SI} = \frac{1}{3} * 78{,}79 + \frac{1}{3} * 0 + \frac{1}{9} * 0 + \frac{1}{9} * 100 + \frac{1}{9} * 0 = 37{,}37$$

7.7. Paper rice packaging

Results for weight measures:

Weight measures (g)								Average weight (g)
11,3	11,4	11,5	11,4	11,5	11,5	11,5	11,4	11,4375

Table 36: Weight measures and average weight for a paper rice packaging of 1Kg (g)

Carbon footprint expressed in kilograms of carbon dioxide per kilogram of product:

Average weight (Kg)	Emission factor ($KgCO_2e/Kg$)	Carbon footprint ($KgCO_2e$)	Product quantity (Kg)	Carbon footprint ($KgCO_2e$/Kg of product)
11,4375E-03	3,32E-05	3,80E-04	1	3,80E-04

Table 37: Calculation of carbon footprint indicator (KgCO2e/Kg of product)

Product price expressed in Euros per kilogram of product:

Actual product price (€)	Product quantity (Kg)	Product price (€/Kg of product)
1,52	1	1,52

Table 38: Calculation of product price indicator (€/Kg of product)

Value for money, product preservation and openability:

Value for money	Product preservation	Openability
1,99	2,5	2,35

Table 39: Social indicators

Values of indicators measured in a scale of 100 points:

Indicator	Actual value	Target value	Packaging range	Indicator value
Carbon footprint	3,80E-04	3,80E-04	2,31E-03	100
Product price	1,52	1,40	6,01	98,0
Value for money	1,99	2,50	0,66	22,73
Product preservation	2,5	2,72	0,61	63,93
Openability	2,35	2,74	0,4	2,5

Table 40: Values for indicators (100 point scale)

Sustainability index for a paper rice packaging with 1Kg of product:

$$\mathrm{SI} = \frac{1}{3} * 100 + \frac{1}{3} * 98{,}0 + \frac{1}{9} * 22{,}73 + \frac{1}{9} * 63{,}93 + \frac{1}{9} * 2{,}5 = 75{,}91$$

7.8. Index comparisons

After indexes calculation, the sustainable performance is analysed and compared among the seven packaging.

Packaging	Sustainability index
Metallic can of cola	54,04
Plastic bottle of cola	63,53
Plastic egg carton	49,81
Cardboard egg carton	65,70
Plastic yogurt cup	79,85
Glass yogurt cup	37,37
Rice paper packaging	75,91

Table 41: Sustainability indexes

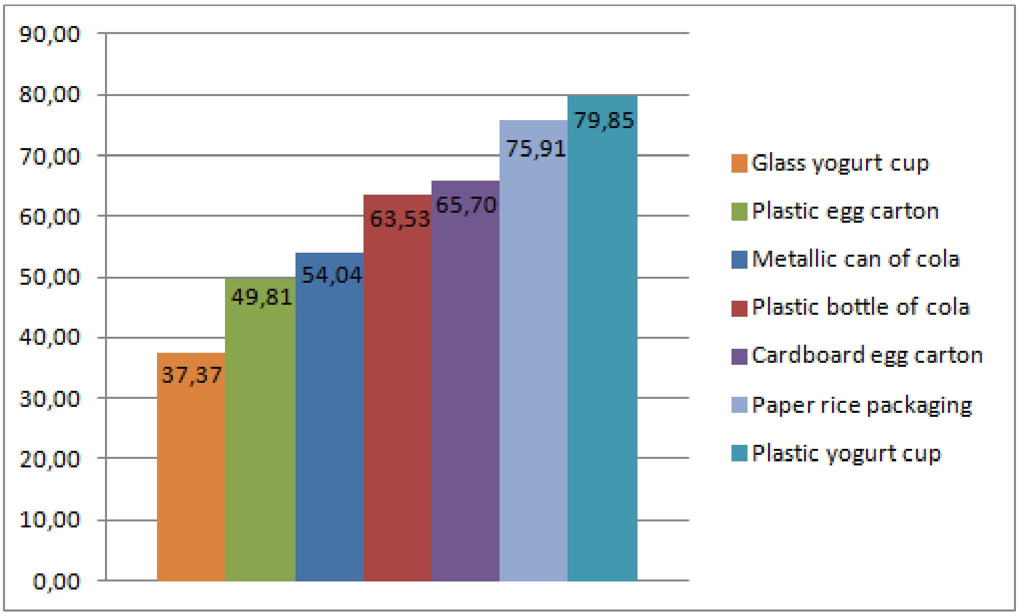

Figure 8: Sustainability indexes

It must be remembered that the sustainability index has a relative character, and then plastic yogurt cup is the best sustainable performer of the studied packaging but it could be the worst if we compare it with other group of containers which have higher indicator values.

According to figure 8, plastic yogurt cup is the best sustainable performing packaging with 79,85 points and it is followed by paper rice packaging, cardboard egg carton, plastic bottle of cola, metallic can of cola, plastic egg carton and glass yogurt cup.

Containers can be classified in three groups: best performers, medium performers and worst performers.

- Best performers: Plastic yogurt cup and paper rice packaging form this group and both of them have obtained a sustainability index above the 70 points, a score than can be considered highly satisfactory.

- Medium performers: Containers classified in this group have a sustainability index between 50 and 70 points, so that they are moderately sustainable. Cardboard egg carton, plastic bottle of cola and metallic can of cola are found in this range.

- Worst performers: These are containers that have ‘failed’ the sustainability exam since they have scored lower than 50 points. Then, plastic egg carton and glass yogurt cup, especially the last one with 37,37, are the worst performers in terms of sustainability.

For now, it has been only compared the overall score of sustainability that gives a general idea about the sustainable behaviour. This could drive to a wrong perception about packaging because obtaining a high sustainability index does not imply high values in all indicators. There is possibility for packaging that scores poorly on environment but highly in economy and society; hence due to the economic and social contributions their sustainability index is acceptable. This is the reason why indicators are going to be examined separately starting for the best performers.

7.8.1. Plastic yogurt cup

Sustainable indicators for plastic yogurt cup:

Indicator	Indicator value
Carbon footprint	63,20
Product price	90,02
Value for money	100
Product preservation	59,02
Openability	100

Table 42: Indicators' values for plastic yogurt cup

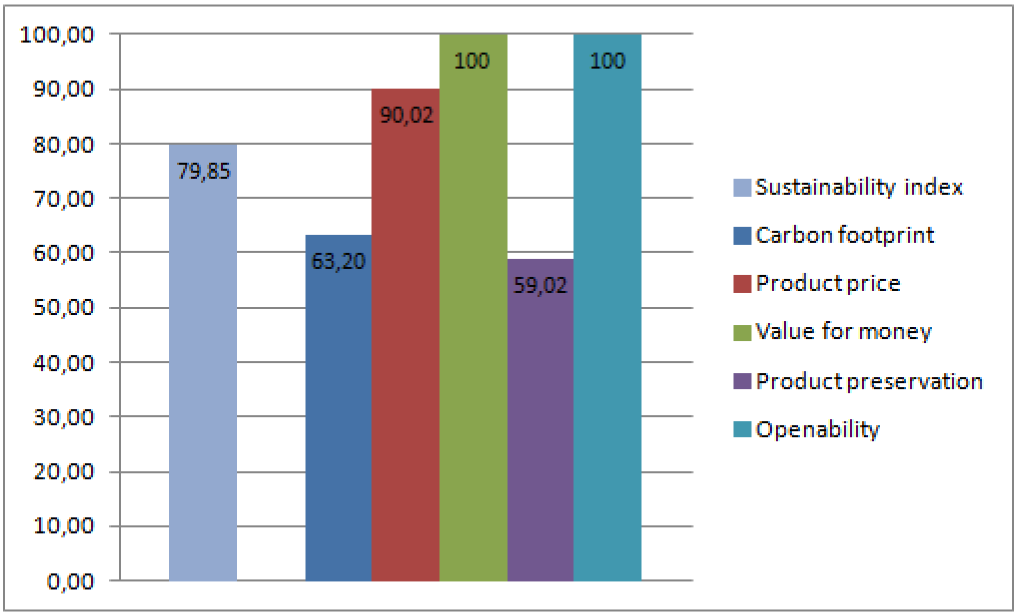

Figure 9: Indicators' values for plastic yogurt cup

Figure 9 reveals that plastic yogurt cup is the best performer thanks to product price, value for money and openability; especially the social indicators that have the maximum value.

On the other hand, product preservation and carbon footprint do not contribute with such high values but they are above the 50 points so we consider them acceptable.

7.8.2. Paper rice packaging

Sustainable indicators for paper rice packaging:

Indicator	Indicator value
Carbon footprint	100
Product price	98,0
Value for money	22,73
Product preservation	63,93
Openability	2,5

Table 43: Indicators' values for paper rice packaging

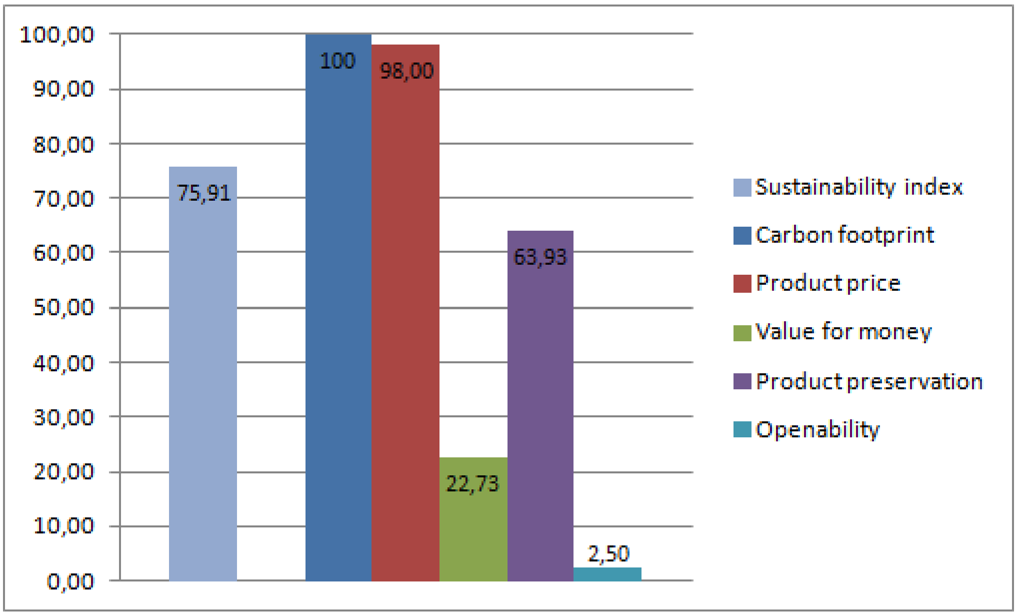

Figure 10: Indicators' values for paper rice packaging

Paper rice packaging produces the fewest emissions of carbon dioxide so the environmental indicator has 100 points; the economic indicator is high too, with 98 points. However, social indicators are not so well rated: product preservation is the only one with an acceptable value of 63,93 whereas value for money has 22,73 and openability only reaches 2,5 points.

As it has been said before, paper rice packaging could seem to be an overall good performer but looking in detail it is appreciated its low social behaviour.

7.8.3. Cardboard egg carton

Sustainable indicators for cardboard egg carton:

Indicator	Indicator value
Carbon footprint	13,42
Product price	100
Value for money	96,97
Product preservation	54,10
Openability	100

Table 44: Indicators' values for cardboard egg carton

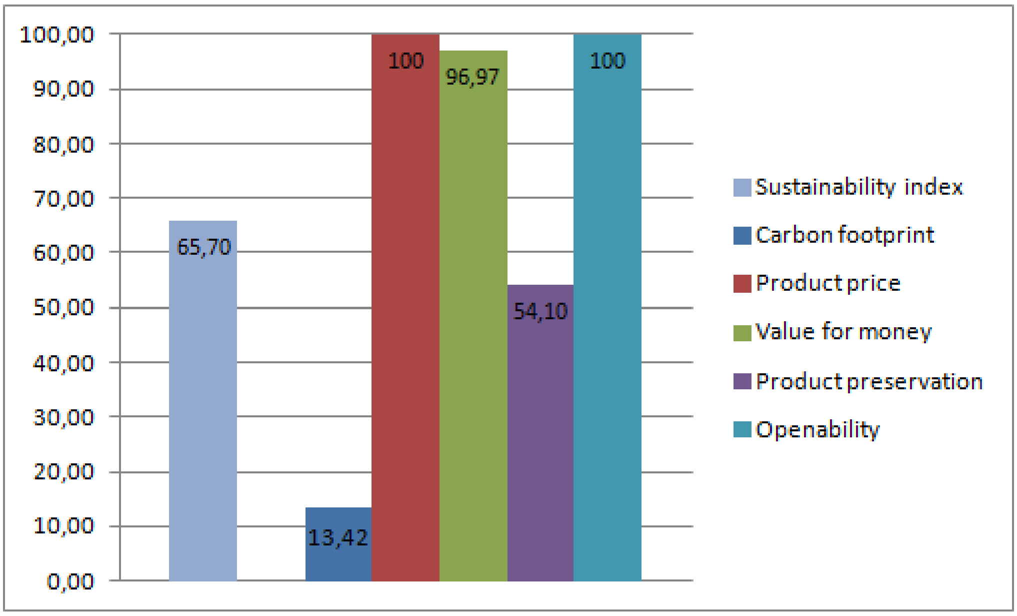

Figure 11: Indicators' values for cardboard egg carton

Cardboard egg carton scores highly on value for money and with the maximum points in product price and openability, but it is carbon footprint the indicator that decreases its sustainability index. Product preservation shows a medium score of 54,1 points.

7.8.4. Plastic bottle of cola

Sustainable indicators for plastic bottle of cola:

Indicator	Indicator value
Carbon footprint	41,99
Product price	97,84
Value for money	39,39
Product preservation	27,87
Openability	85

Table 45: Indicators' values for plastic bottle of cola

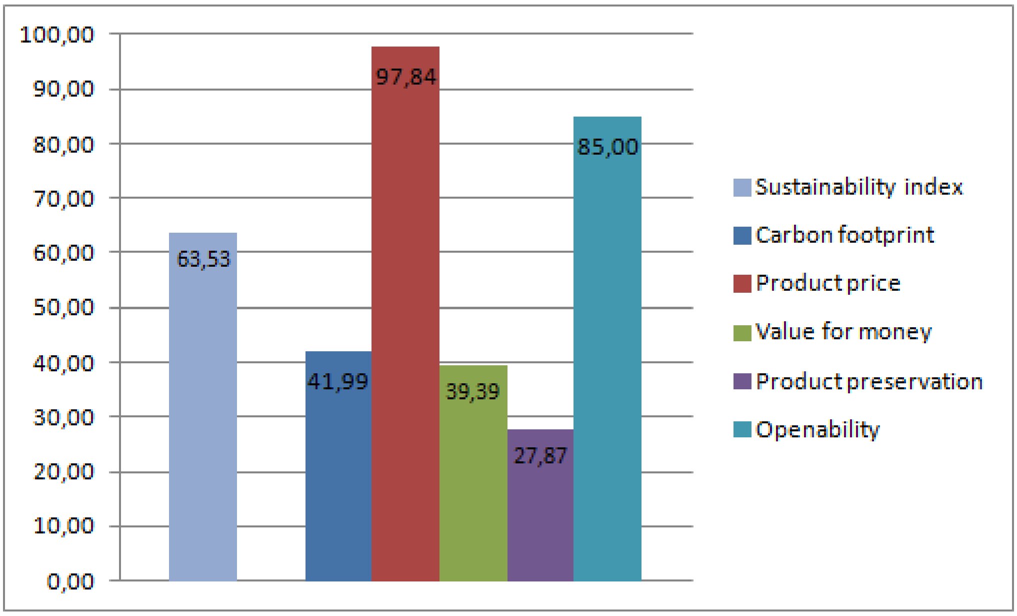

Figure 12: Indicators' values for plastic bottle of cola

The sustainability index for plastic bottle of cola is more than 2 points below the index for cardboard egg carton. Both of them have high values in product price and openability but the bottle of cola is lowly rated in the rest of indicators.

7.8.5. Metallic can of cola

Sustainable indicators for metallic can of cola:

Indicator	Indicator value
Carbon footprint	0
Product price	94,68
Value for money	46,97
Product preservation	80,33
Openability	75

Table 46: Indicators' values for metallic can of cola

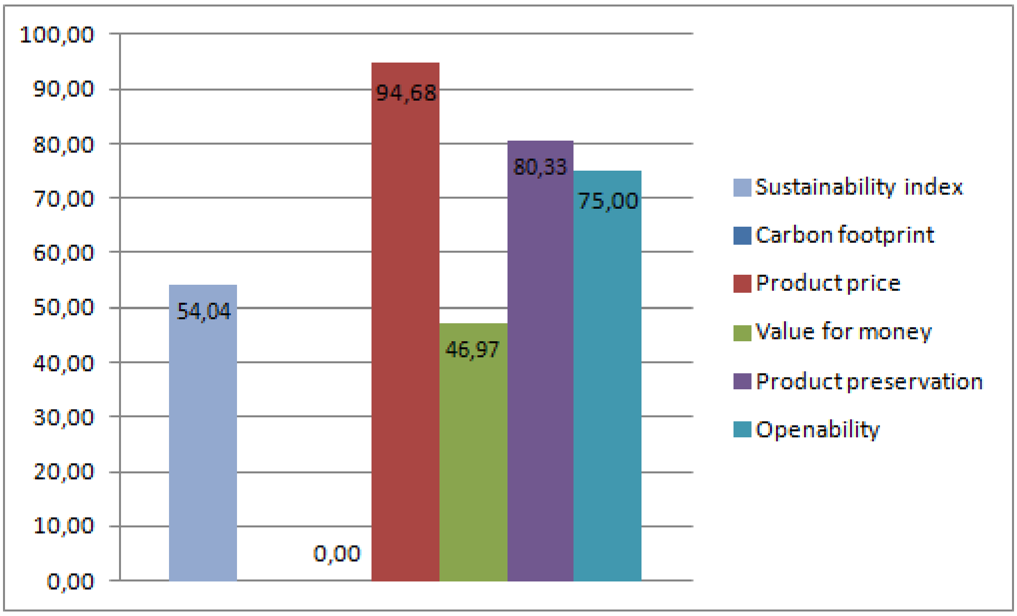

Figure 13: Indicators' values for metallic can of cola

Figure 13 reveals metallic can of cola only reaches 54,04 points due to a medium score in value for money combined with the lowest value in carbon footprint. Product price is its best indicator value and product preservation and openability are well rated by consumers' opinion.

7.8.6. Plastic egg carton

Sustainable indicators for plastic egg carton:

Indicator	Indicator value
Carbon footprint	38,96
Product price	94,18
Value for money	36,36
Product preservation	0
Openability	12,5

Table 47: Indicators' values for plastic egg carton

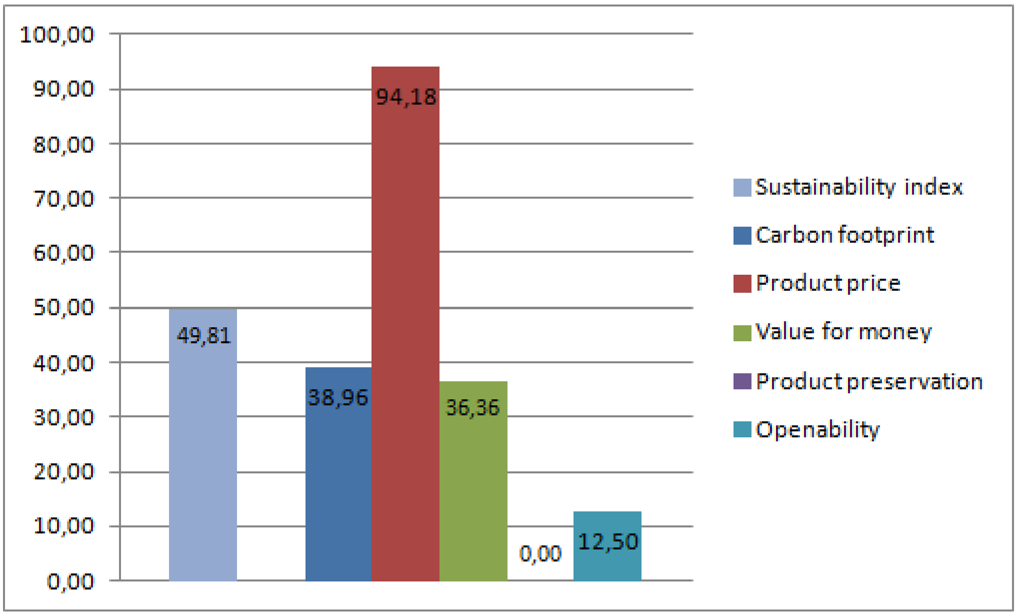

Figure 14: Indicators' values for plastic egg carton

Plastic egg carton only shows a high value in the economic indicator while the contribution of the others is low or even zero in the case of product preservation.

7.8.7. Glass yogurt cup

Sustainable indicators for glass yogurt cup:

Indicator	Indicator value
Carbon footprint	78,79
Product price	0
Value for money	0
Product preservation	100
Openability	0

Table 48: Indicators' values for glass yogurt cup

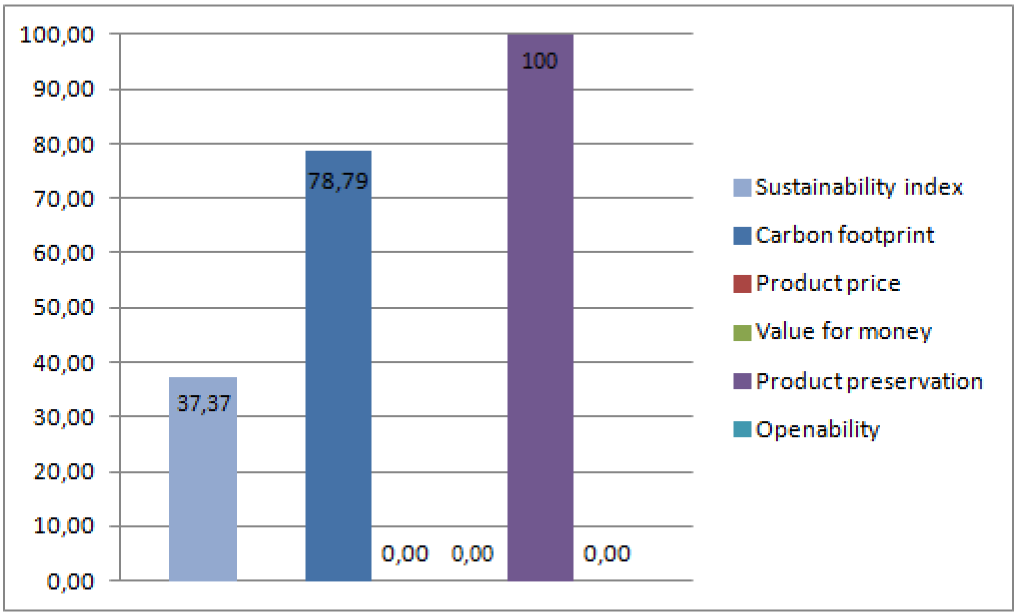

Figure 15: Indicators' value for glass yogurt cup

Glass yogurt cup is the worst performer with 37,37 points though it has high values in carbon footprint and product preservation; in fact product preservation scores 100. The index is so low because of product price, value for money and openability which have 0 points.

7.8.8. Indicators comparison according to the packaged product

Now containers that preserve the same product are compared so it is deduced which one of them is better in terms of sustainability.

Cola is the first product to analyse:

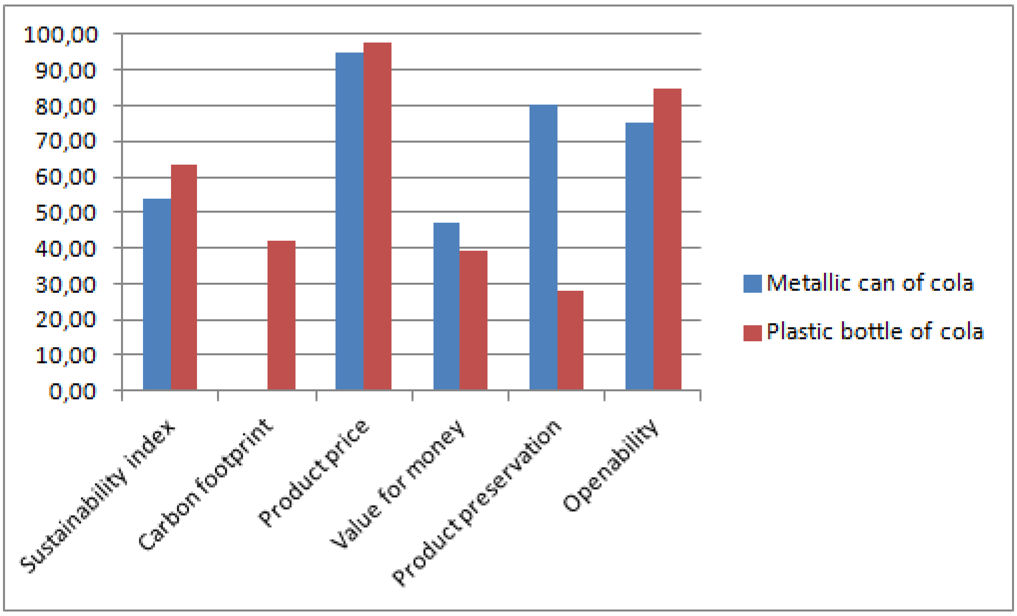

Figure 16: Comparison between cola containers

The sustainability index tells us the plastic bottle is more sustainable than the metallic can and we can see it is true for the indicators of carbon footprint, product price and openability. The plastic bottle only shows worse results in value for money and product preservation with more than 50 points of difference in the last one.

Now, eggs' containers are compared:

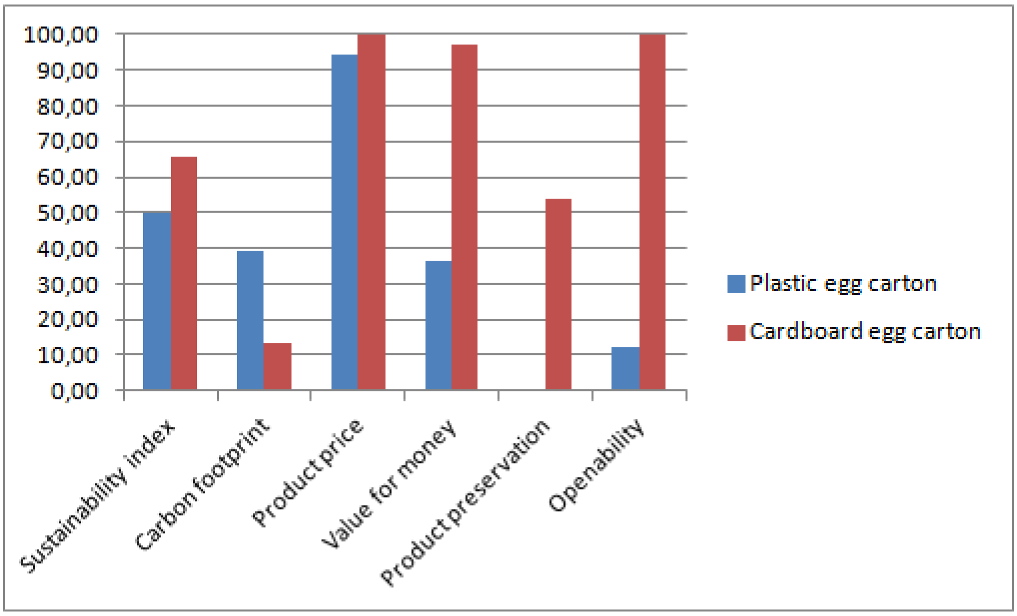

Figure 17: Comparison between eggs' containers

It is noticeable the advantage of cardboard packaging over plastic container in social indicators, where plastic material is the worst rated in product preservation and it does not obtain satisfactory results in the others either. Product price indicator gets high scores in both of the packaging and carbon footprint is the only indicator in which plastic egg carton is higher.

Finally, yogurts' cups are analysed:

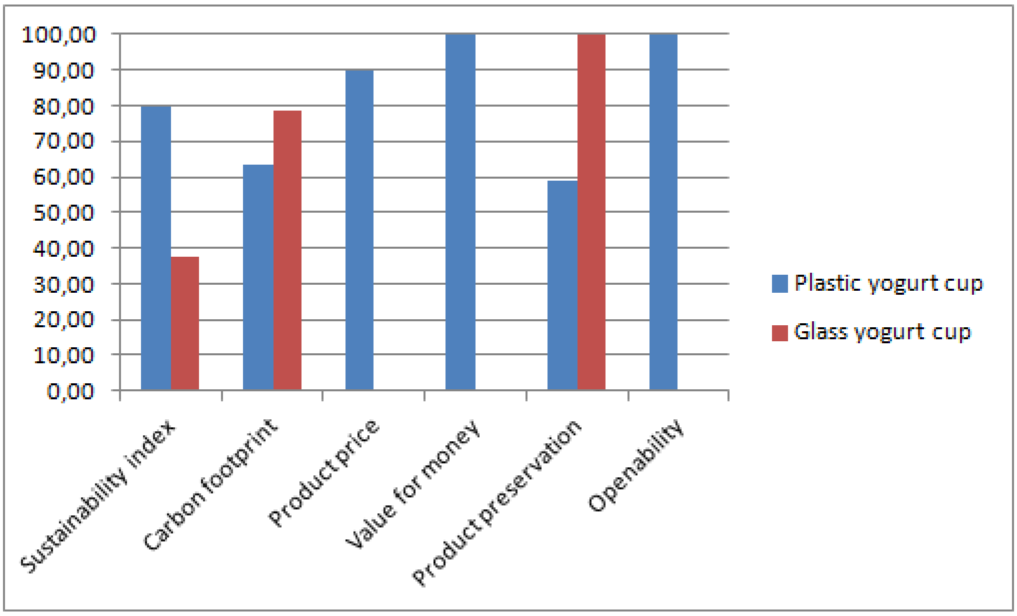

Figure 18: Comparison between yogurts' containers

Although the glass cup has higher results in carbon footprint and product preservation, it does not get any points in product price, value for money and openability, for what plastic yogurt cup doubles the sustainability index of the glass cup.

7.9. Behaviour towards sustainability

The survey conducted to 201 consumers asked them, apart from the social variables related to the packages, if they would be willing to pay a higher price for products with sustainable packaging.

The responses will be analysed taking into account sociodemographic variables: Sex and age.

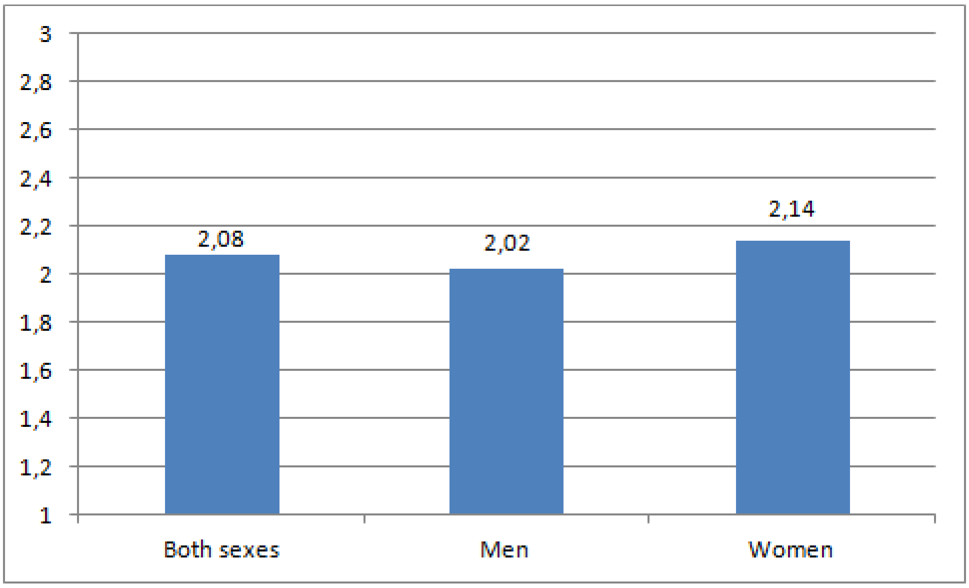

Figure 19: Mean of responses. Sociodemographic variable: Sex

Figure 19 shows the mean of responses of all consumers is 2,08, where the minimum value is 1 and the maximum is 3. Therefore, participants present a neutral willingness in the purchase of a product with a sustainable packaging.

Though there is not much difference in behaviour between men and women, the latter group scores higher than men and the total of participants with a value of 2,14.

Now, figure 20 shows results focusing on participants' age.

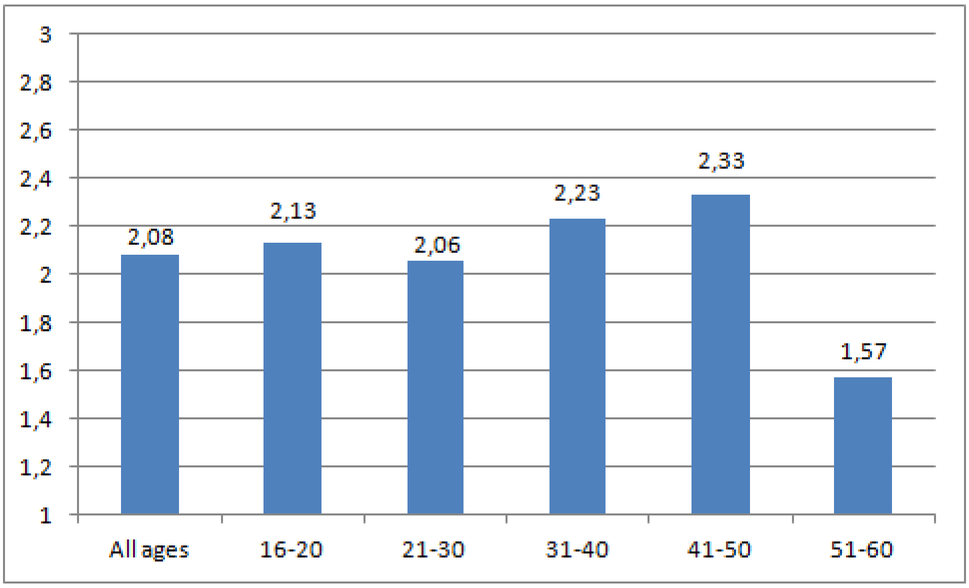

Figure 20: Mean of responses. Sociodemographic variable: Age

Participants who are in the age range from 16 to 30 years present a mean value near to 2,08, which is the mean of all consumers. The participants groups of 31-40 and 41-50 have higher values, being the latter group the best scoring one with 2,33. The worst mean is found in consumers between 51 and 60 years with 1,57, and then this is the least sustainably conscious generation.

It must be reminded that the participation was not equal among all ages, having the two youngest groups the greatest share. Then, some means may not be representative of their age group.

7.10. Redesign of packaging

The redesign will focus on the paper rice packaging which contains 1Kg of product.

Firstly, the worst scoring variable of the paper rice packaging is openability. Then, its redesign must focus on creating a more comfortable and easier opening system.

Secondly, the new package should be simple and mono-material so that to avoid complex and expensive production processes [58].

The selected material for the container should be a non virgin resource that has already been used and treated. In this way, waste generated by other package whose useful life has ended is converted to resource for a new container. This is in line with one of the basic concepts of the Cradle to Cradle design: Waste equals food [27].

Finally, the container should be made of a material with an extended recycling process [58]. Figure 21 shows the recycled quantity of the main packaging materials used in Spain: Paper and cardboard, glass, plastics and metals.

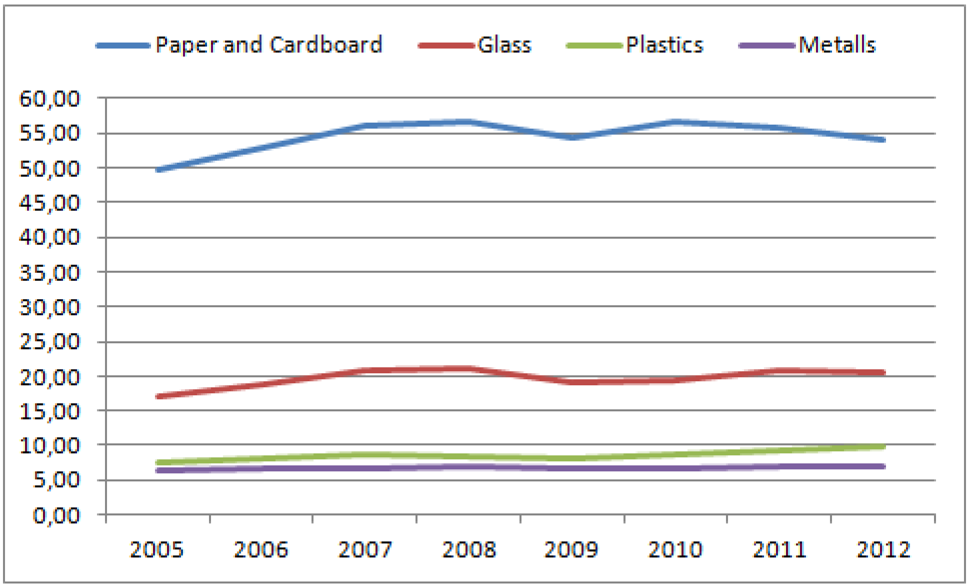

Figure 21: Kilograms of recycled packaging material per capita, Spain, 2005-2012 [59]

Noticeably, paper and cardboard are the most recycled materials in Spain, followed by glass, plastics and metals.

The material that meets all the requirements is thin cardboard made of recycled vegetal fibres. This is a non virgin material that can be recycled and whose rigidness will help to make an easy-to-open system.

One of the life cycle phases that will condition the design is the distribution to market. In order to produce fewer carbon emissions and costs, the shape of the container will be rectangular since this will enable to fill the available space efficiently; rounded bodies present the packing problem that leads them to waste space in their storage [60].

The size and shape of the container should provide a good handleability at the same time that it holds 1 kilogram of rice. Then, dimensions will be 200mm x 100mm x 70mm.

The first opening system is based on a slide mechanism that enables the consumer to open and close the package as many times as it is needed.

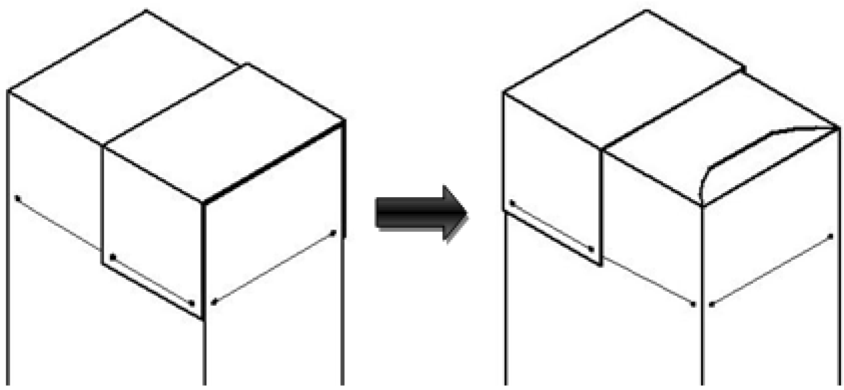

Illustration 9: Slide mechanism

The mechanism is composed of three elements: package, lid and thread. The lid slides along the upper surface of the package driven by a thread as it is shown in illustration 9. There is an aperture that is only covered by the lid in the close position. Before being used for the first time, the package will be open by tearing along the dotted line presented in illustration 10.

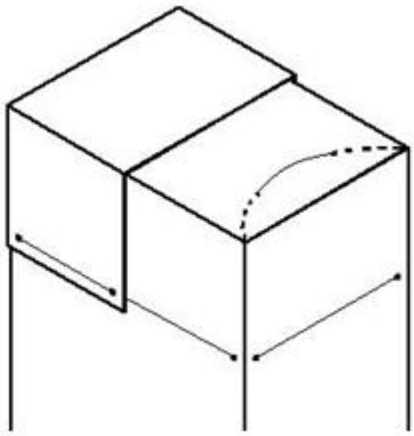

Illustration 10: Package before being used

Illustration 11 shows the drafts for the unfolded parts.

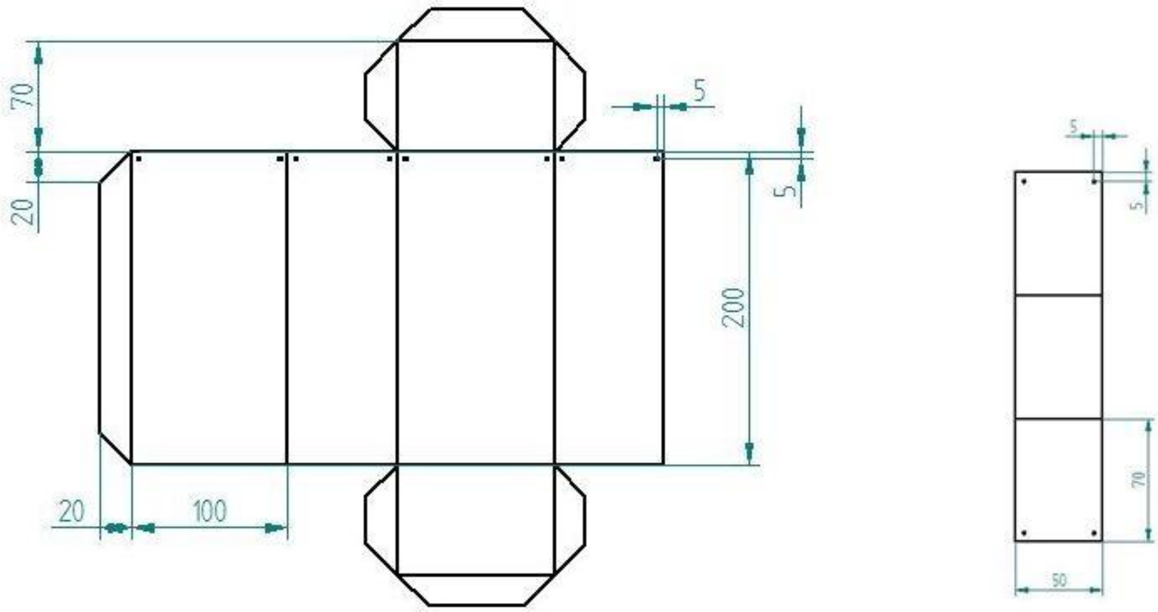

Illustration 11: Package and lid drafts

The disadvantage of this packaging is that it is made of three parts.

In order to improve the package described above and design another one with a simpler production process, a container made of one element is explained below.

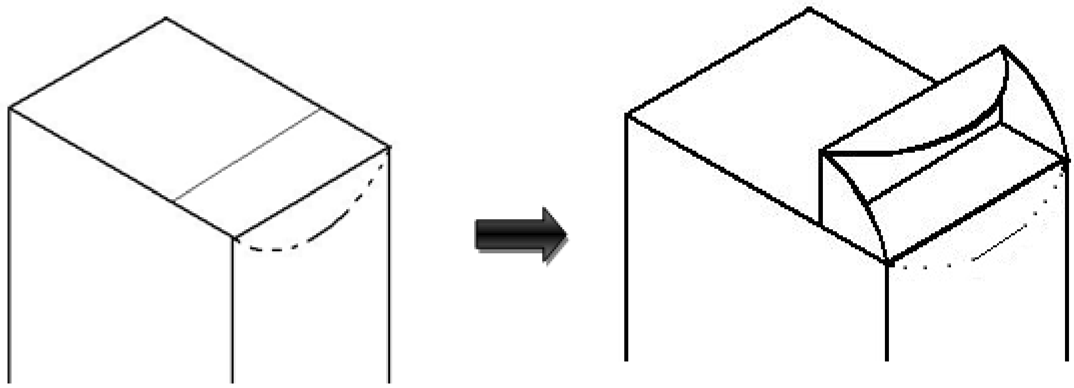

Illustration 12: Opening system

Illustration 12 presents the opening system in which the lid is turned backwards around a folded edge of the container's upper surface. To close it again the lid must be turned to its original position putting the flaps inside the package.

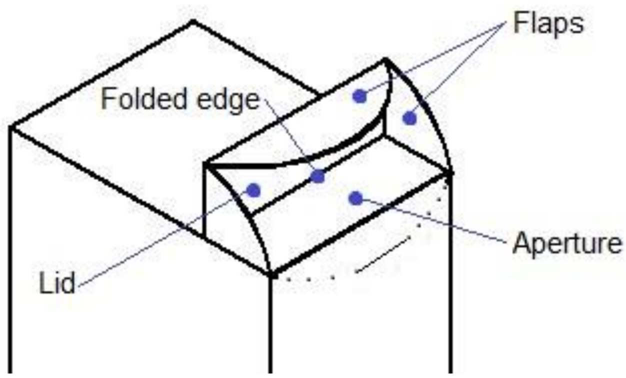

Illustration 13: Opening system description

Illustration 14 is the draft of the unfolded container.

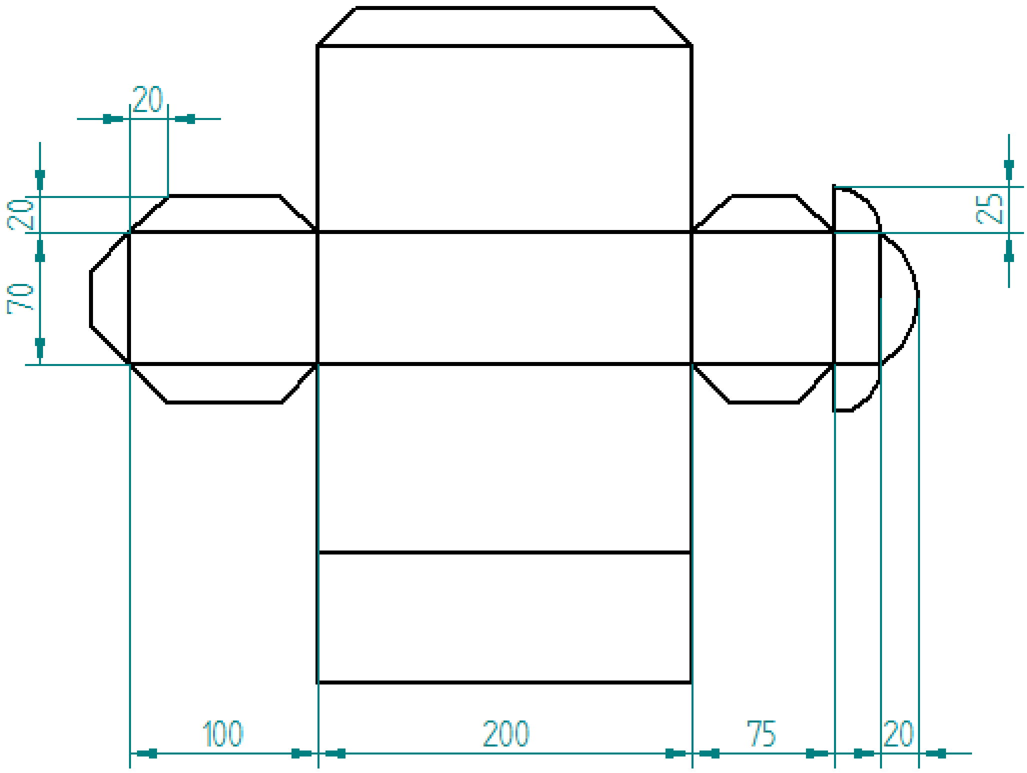

Illustration 14: Unfolded container draft

Illustration 15 is an isometric view of the packaging in the open position.

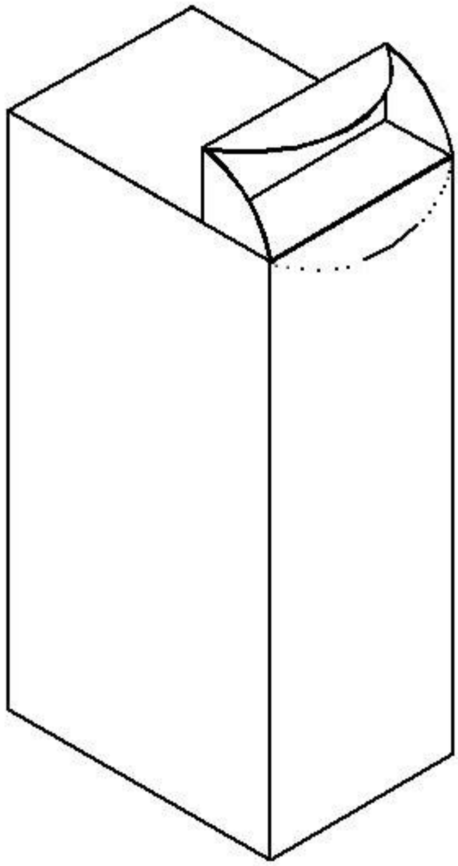

Illustration 15: Cardboard rice packaging

8. Conclusions

The Sustainability Index offers a measuring tool to find strengths and weaknesses in packaging looking at its environmental, economic and social performances. Using this index, a studied has been conducted on seven food and beverage packages that are consumed currently by the majority of households in their daily life.

As a result, plastic yogurt cup was found to obtain the highest Sustainability Index and, on the other hand, glass yogurt cup scored the lowest one. Here it is noticeable how different packages of the same product can highly diverge in their sustainable performance.

Then, paper rice packaging was redesign to improve its openability. For that purpose, cardboard was selected as the packaging material due to its rigidness that would enable to create a more suitable opening system. Apart from that property, cardboard is a biodegradable material that can be recycled and used to manufacture new packaging, creating a closed loop cycle as it is suggested in the Cradle to Cradle model [27].

Finally, future research lines for the project are presented:

- More variables need to be aggregated to the index so it can be obtained a more accurate one. Examples of new environmental indicators are renewable energy proportion used in the production process, water consumption or toxicants concentration. For the economic indicators, total packaging cost could be taken in account so as to analyse the cost related only to the package. Finally, packaging safety would be another interesting variable for social indicators [46].
- The survey used for the social indicators needs to be equally conducted on all ages since the actual one presents 71,14% of participants who are only in the age range of 16 to 30 years.
- The survey only takes into account two sociodemographic variables: Sex and age. Another variable to be included could be the education level since it is regarded with the environmental awareness [61, 62].
- Transform the relative character of the index into absolute. Instead of using the best performing packaging value, targets can be set based on national policy goals, international organizations, scientific criteria or expert judgement [55].

9. Plan and budget

This project was conducted following a Gantt chart, as it is shown in figure 22, in order to meet the deadline date. As it can be noticed, the sections that took longer time to complete were methodology and results.

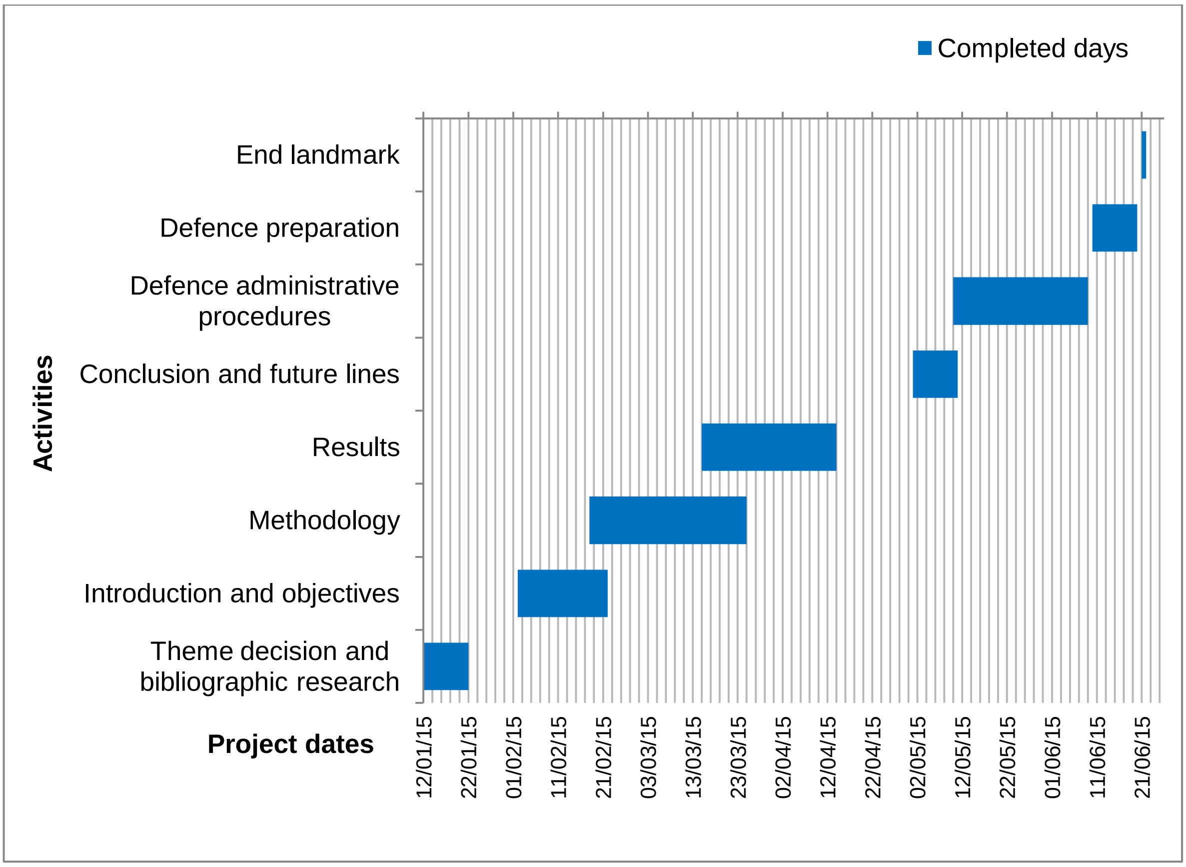

Figure 22: Gantt chart for time management

The budget related to this project for a company with expertise in packaging that would like to asses some of its products is divided in three stages.

The first stage is collecting data and calculating indicators of the selected packages to asses, once methodology has been understood. Then, the Sustainability Index can be calculated using the indicators.

The second stage consists in analysing the results obtained. Here it is where the company finds out which package is the best sustainable performing as well as strengths and weaknesses of all the studied products.

Finally, the third stage is implementing improvements in those packages that need to enhance their sustainable performance.

The budget will vary depending on the quantity of packages to asses and the redesigning. Therefore, the Gantt chart presented above will serve as guidance to determine the time spent in the three stages. Each day represents 8 working hours and each hour costs 25€.

The budget related to the third stage is the most variable due to the kind of modification to implement in the package, so table 49 serves only as approximation.

Concept	**Time spent (days)**	**Price (€)**
First stage	35	7.000
Second stage	30	6.000
Third stage	30	6.000
Total	95	19.000

Table 49: Project budget

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